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CONTENTS

Study of Atmospheric Absorption and Emission in the Infrared Spectrum . . JOHN STRONG 1

Some Observations on Electrical Discharges from Pointed Conductors . . JOHN ZELENY 23

Overhead By-Pass Gas Pipe System . . . . . JACOB FELD 39

Notes from the National Bureau of Standards 59

The Franklin Institute Notes 65

Notes from the Bartol Research Foundation 68

Notes from the Biochemical Research Foundation 76

Book Reviews 87

Publications Received 96

Current Topics 38, 58, 97

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STUDY OF ATMOSPHERIC ABSORPTION AND EMISSION IN THE INFRARED SPECTRUM.

BY

JOHN STRONG,

California Institute of Technology.

Introduction.—Langley's method for the management of solar radiation data is to plot the logarithm of a measured radiation intensity, as ordinate, against the secant of the zenith distance of the sun, as abscissa. Beer's law (Eq. 1) forms the physical basis for this procedure. Langley's method is justified for measurements in the visible and ultraviolet spectral regions because Rayleigh scattering, particle scattering and ozone absorption predominate as attenuating agencies in the atmosphere there.

The transmission of the atmosphere is, according to Beer's law:

$$T = 10^{-(\alpha_1+\alpha_2+\cdots)\sec z}. \qquad (1)$$

The various α's are the optical densities of one air mass for the various mentioned attenuating agencies. Sec z is the number of air masses penetrated by the solar radiation. Plotting intensity measurements as described above, on a so-called Langley diagram, defines a straight line which, extrapolated to zero air mass, yields the solar intensity incident on the outer boundary of the atmosphere.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

Ångstrom [1] first, and other authors [2] subsequently, have shown that Beer's law does not apply to band absorption in the infrared spectrum.

The purpose of the present publication is to show the method by which atmospheric emission and solar absorption measurements in the infrared spectrum may be managed in order to define straight lines. The new method is to plot the intensity of radiation, as ordinate, against the square root of the number of air masses (or square root of the amount of water vapor) in the line of sight, as abscissa.

The square root dependence of absorption (and consequently of emission) on the amount of absorbing gas penetrated is a special case of a general result first anticipated by Ladenburg and Reiche who integrated the energy absorbed by a strong line for various thicknesses of optical path.[3] The over-all absorption produced by a band of strong lines, such as an infrared absorption band, is therefore expected, within certain limits, proportional to the square root of the amount of the absorbing gas penetrated.

By plotting atmospheric absorption data after the manner of Langley as well as in the new manner, it is possible, on the one hand, to decide if a given atmospheric absorption is due to an essentially continuous spectrum or, on the other hand, if it is due to a band spectrum: the plot for the first type of spectrum defines a straight line on a Langley diagram while the plot for the second type defines a straight line when plotted in the new manner. (The more obvious method of distinguishing between continuous and band absorption, or emission, by employing spectral resolution is not always applicable owing to the difficulty of obtaining adequate resolution.)

The Work of Elsasser and Adel.—Elsasser [3] has ingeniously predicted a continuous atmospheric absorption due to water vapor in the spectral interval 8–13½ μ—the so-called "window" in the atmosphere. This "window" is depicted by the dashed curve, the transmission of the atmosphere plotted in Fig. 1.

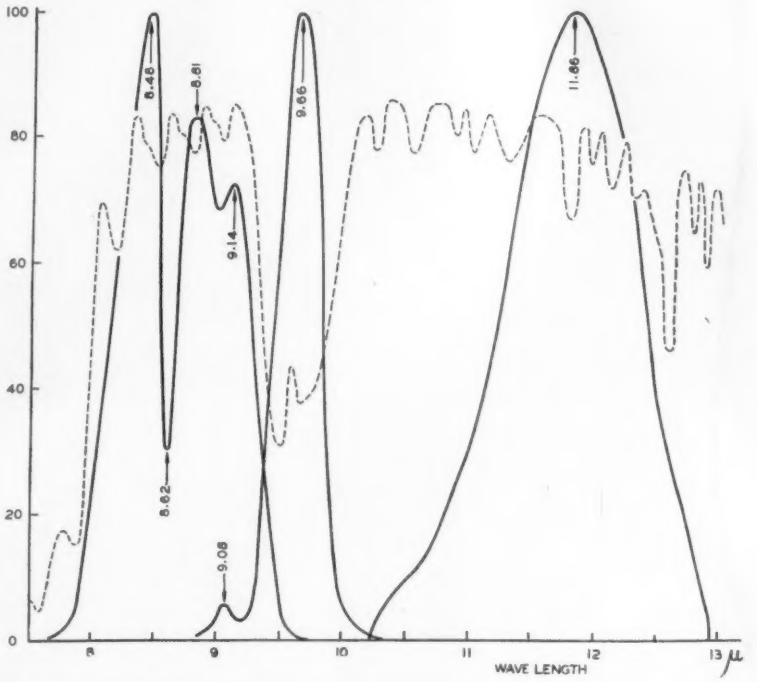
[1] K. Ångstrom, *Ann. d. Phys.*, **6**, 163 (1901).

[2] Eva v. Bahr, *Ann. d. Phys.*, **29**, 780 (1909); **33**, 585 (1910); *Verh. d. D. Phys. Ges.*, **15**, 673 and 710 (1913). G. Hertz, *Verh. d. D. Phys. Ges.*, **13**, 617 (1911).

[3] R. Ladenburg and F. Reiche, *Ann. d. Phys.*, **42**, 181 (1912). D. M. Dennison, *Phys. Rev.*, **31**, 503 (1928). C. L. Pekeris, *Astrophys. Jour.*, **79**, 441 (1934). W. M. Elsasser, *Phys. Rev.*, **54**, 126 (1938).

Both the author, here, and Dr. A. Adel, at Flagstaff, have made quantitative measurements of the solar radiation transmitted through the "window." The author's measurements

FIG. 1.



Dashed line—transmission of the atmosphere when there is 1 cm. of precipitable water vapor overhead. Full lines are the residual ray response bands of five quartz crystals at 8.8μ, of five apophyllite crystals at 9.66μ and of five silicon carbide crystals at 11.86μ. Note the coincidence of the apophyllite residual ray band with the 9.6μ atmospheric ozone absorption.

will be described below. Adel regards his measurements as support for Elsasser's theory of continuous absorption.[4]

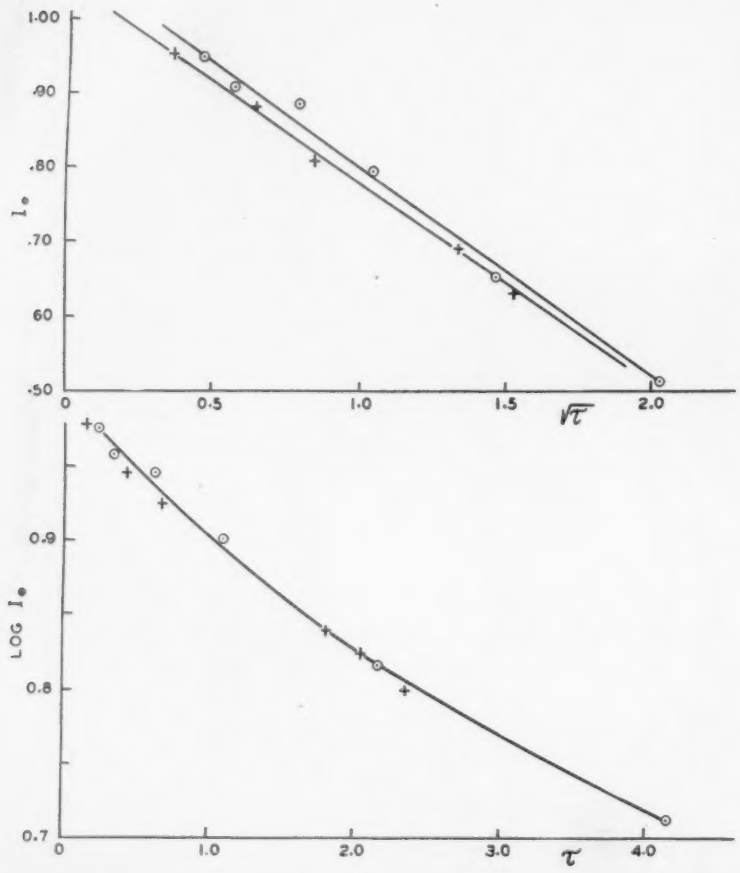
In Fig. 2 are plotted later selected measurements of Adel [5] which he says are typical of his many measurements made. These later measurements are plotted on a Langley diagram as well as in the new manner. Neither method of plotting closely defines a straight line, but the new method appears to

[4] A. Adel, *Astrophys. Jour.*, **89**, 1 (1939).

[5] A. Adel, *Astrophys. Jour.*, **91**, 487 (1940).

be the favored one. It is questioned whether these later measurements support Elsasser's theory of continuous absorption or whether, on the other hand, they indicate band type absorption.

FIG. 2.

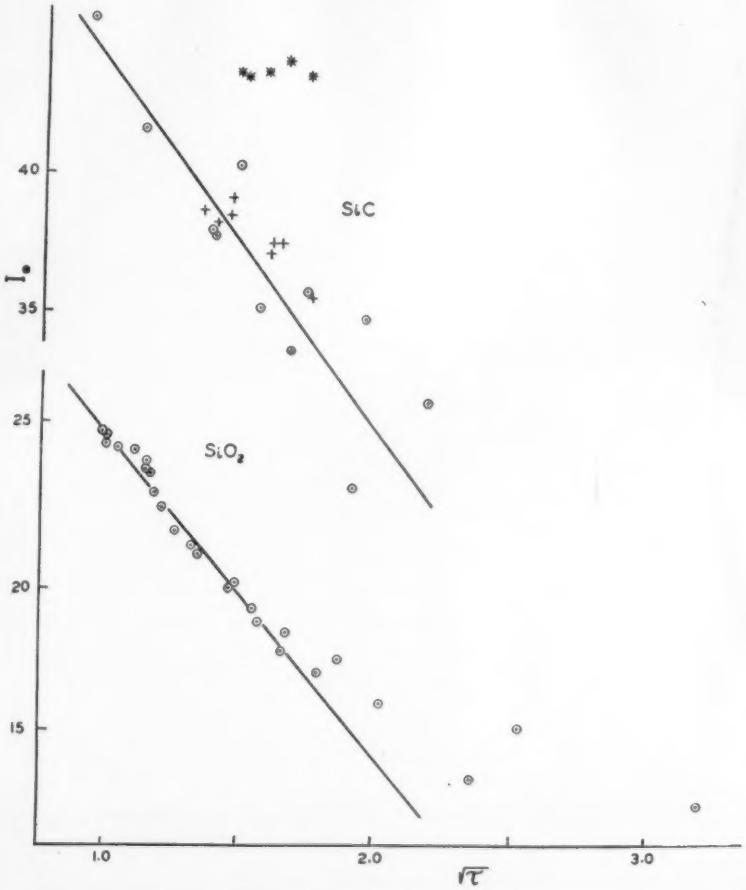


Data of Adel [5] averaged for 8–9μ and 10–11μ and plotted as ⊙. Data of Adel averaged for 11–12μ and 12–13μ and plotted as +.

Solar Absorption Measurements with Residual Rays.—Using a residual ray apparatus, the author has made measurements of solar radiation within the "window." At the same time that these measurements were made, the amount of water-

vapor penetrated was determined by measurements of solar absorption in the Φ-band. The residual ray apparatus [6] and the Φ-band determination [7] are described elsewhere. In Fig. 1 are given the response bands of the residual ray apparatus at

FIG. 3.



Below—Residual ray response with five quartz crystals and 0.75 mm. filter of LiF. Solar observations of December 12 and 14, 1939 taken at Pasadena. Above—Residual ray response with five SiC crystals. Solar observations of December 18, 19, 20, 24 and 25, 1939 taken at Pasadena, plotted as ⊙. Observations of November 30 and December 1, 1940 taken on Palomar Mountain, plotted as +. November 29, 1940 data plotted as *.

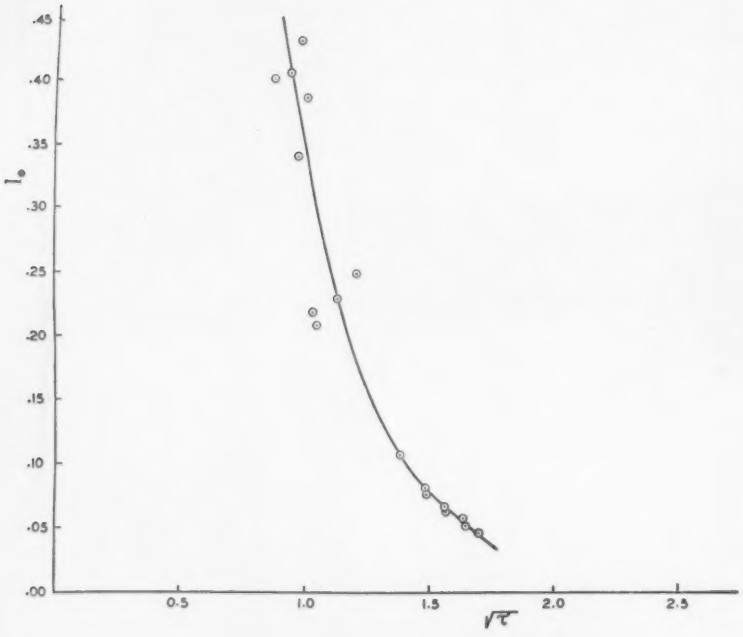
[6] John Strong, *J. O. S. A.*, **29**, 520 (1939).

[7] John Strong, *Jour. of Frank. Inst.*, **231**, 121 (1941).

8.8 μ, using 5 crystals of quartz and a 0.75 mm filter of LiF; at 9.66 μ, using 5 crystals of apophyllite and a 1.14 mm filter of CaF_2; and at 11.86 μ, using 5 crystals of silicon carbide.

The first quantitative measurements in the "window" were made and reported in 1938.[8] They indicated absorption of the order of magnitude predicted by Elsasser. For ex-

FIG. 4.



Residual ray response using five MgO crystals. Solar observations of September 19, 20 and 21, 1940 taken on Palomar Mountain.

ample, the transmission of the atmosphere at Pasadena in the zenith direction for the 8.8 μ band on June 23, 1938 was found, by calculation, to be 85 per cent.

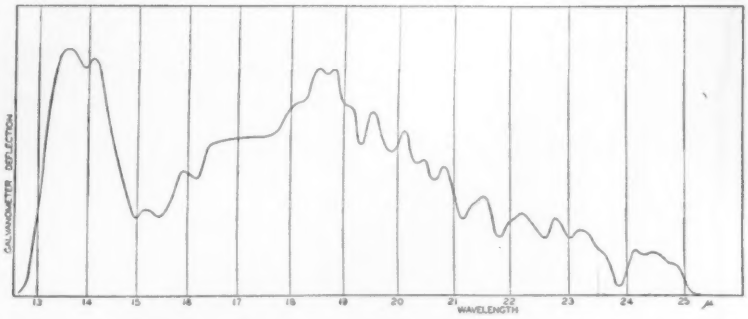
These measurements, as well as subsequent ones, are characterized by fluctuations of the solar energy received. Figure 3 shows measurements of solar radiation at 8.8 and 11.86 μ, respectively. These measurements were made in

[8] John Strong, *Phys. Rev.*, **54**, 242 *A*, (1938).

Pasadena during December 1939. They are plotted in the new manner. Abscissa are the square root of the amounts of water vapor penetrated, expressed as centimeters of precipitable water. Plotting in the new manner yields a better straight line than plotting after the manner of Langley.

Crosses and stars in Fig. 3 represent measurements made a year later on Palomar Mountain with the assistance of Dr. Elsasser. The measurements of November 30 and December 1, 1940 are plotted as crosses. Their mean ordinate is arbitrarily adjusted. On the same scale as the adjusted crosses,

FIG. 5.



MgO residual ray band filtered through about 700 cm. of laboratory air. Note the effect of the CO absorption band at 14.95μ and the water absorption beyond.

the November 29 measurements appear as stars. The idea of making these measurements on Palomar Mountain was to rise above hypothetical gases producing fluctuations of the solar energy received. It is evident that the fluctuations were equally great at the higher station. The constancy of the energy received on November 29, a very clear day, is of particular interest. It signifies an absorbing agency the action of which varied inversely with the absorption of water vapor. It may be remarked that the solar intensity incident on the outer boundary of the atmosphere is assumed to be constant.

The fluctuations are provisionally ascribed to varying amounts of atmospheric constituents, other than water vapor, such as oxides of nitrogen, CO_2, hydrocarbons and formaldehyde.

Solar Absorption Measurements with MgO Residual Rays.—The reflectivity of MgO has been measured in the infrared spectrum.[9] From these measurements it appeared that the five-crystal residual ray band of this material would be re-

FIG. 6.

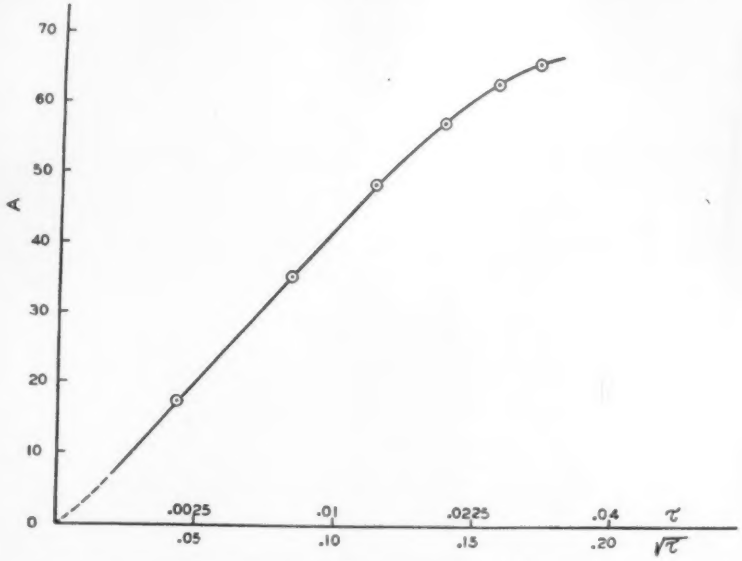
Calcite resudial ray band produced by two crystals (on turrets No. 2 and No. 4) cut perpendicular to the optical axis. 1.61 mm. filter of LiF employed.

sponsive to solar radiation which might penetrate the atmosphere in the spectral region extending from the 14.95 μ CO_2 band throughout the spectrum to 25 μ. Accordingly, the residual ray apparatus fitted with MgO crystals was used to search for solar radiation in the spectrum beyond the CO_2 band at 14.95 μ. The obtained solar response is plotted in Fig. 4 against the square root of the amount of water vapor

[9] John Strong, *Phys. Rev.*, **38**, 1822 (1931). Karl Korth, *Göttingen Nachrichten*, 1, No. 15, 187 (1935).

penetrated. From various subsequent experiments it appeared that this response was due, at least in part, to radiation of wavelengths shorter, rather than longer, than 14.95 μ. The response curve of the residual rays after five reflections from MgO was later measured using a grating spectrometer and the result is given in Fig. 5. The laboratory air path penetrated by the residual rays was about 700 cm and the effects of the

FIG. 7.



Absorption of residual ray band of calcite (see Fig. 6) by water vapor.

absorption band of CO_2 at 14.95 μ [10] and the absorption of water vapor [11] beyond are evident in this curve.

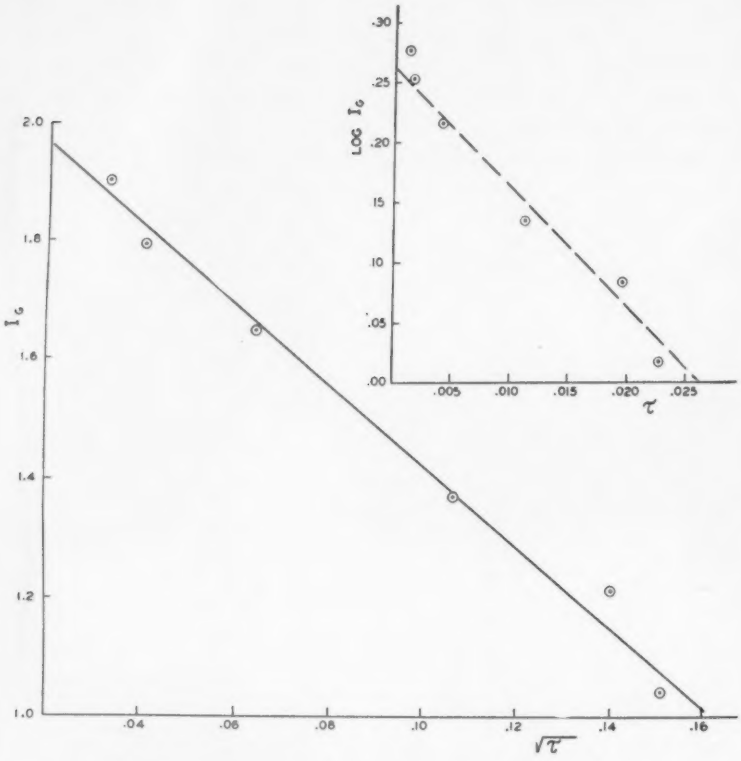
The data of Fig. 4, interpreted with the help of Fig. 5, appear to represent, primarily, the transmission characteristics of the extreme red limit of the "window." The existence of solar radiation beyond 14.95 μ is doubted by other authors.[12]

[10] For the appearance of the CO_2 band see P. E. Martin and E. F. Barker, *Phys. Rev.*, **41**, 291 (1932).

[11] Compare with Louis Russell Weber and H. M. Randall, *Phys. Rev.*, **40**, 835 (1932).

[12] A. Adel, V. M. Slipher and E. F. Barker, *Phys. Rev.*, **47**, 580 (1935).

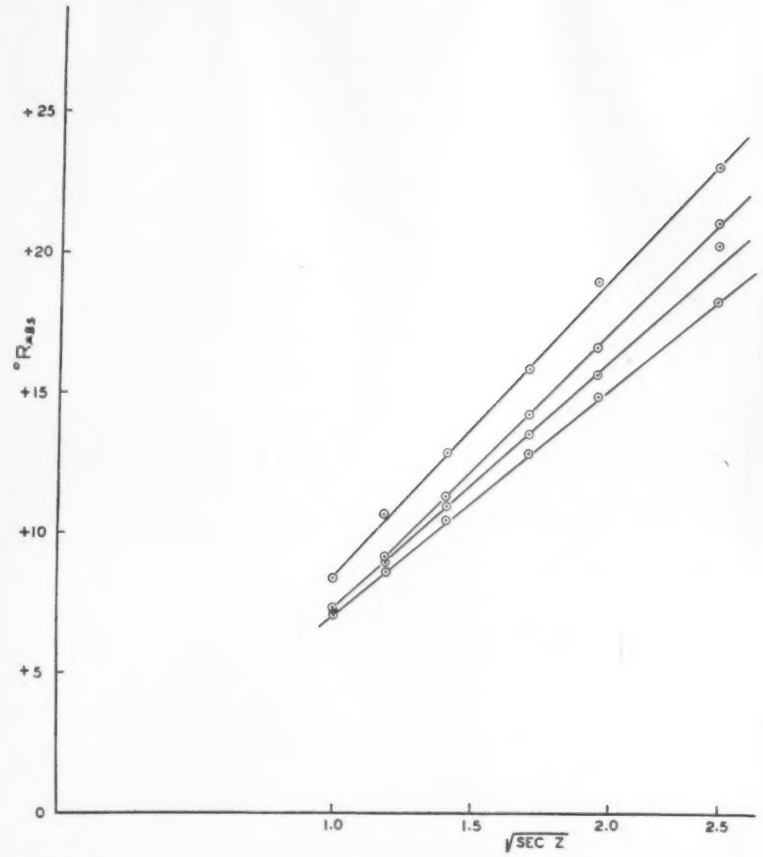
FIG. 8.



Residual ray response at 21μ as function of water vapor penetrated.

Measurements of Water Vapor Absorption in the 6.3 μ Band.—The absorption of water vapor by the long-wave branch of the 6.3 μ band was measured using the calcite residual ray band depicted in Fig. 6. The source was a black body at 80° C. and the radiation incident on the measured optical path had been filtered through about 3.5×10^{-4} cm of water vapor. Absolute humidities of the air were determined by weighing the water vapor absorbed from a definite sample of the air by a magnesium perchlorate drying tube. These humidities served in calculating the amount of water vapor penetrated. The fractional absorption is plotted in Fig. 7 against the square root of the amount of water vapor penetrated (ex-

FIG. 9.



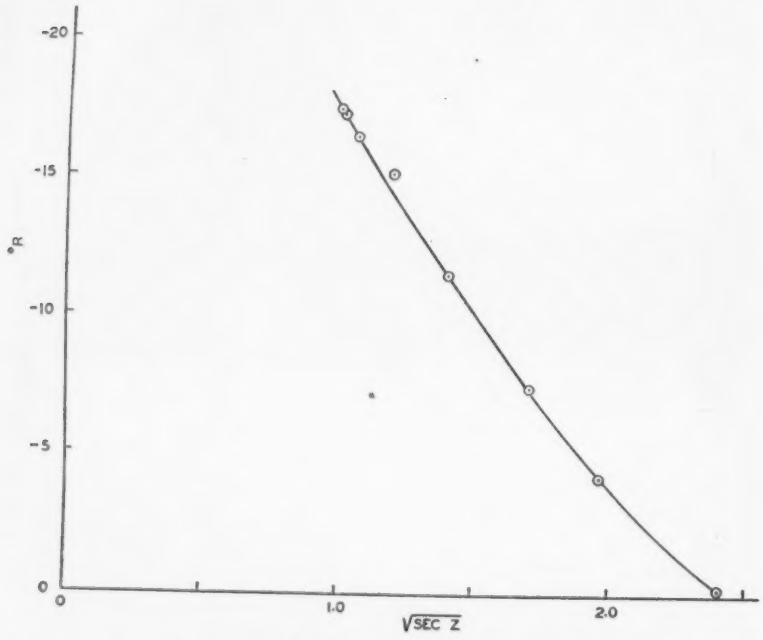
Quartz residual ray response produced by sky emission. Ordinates are degrees on the linear radiation scale above absolute cold. Observations were made December 4 and 5, 1938. Times of observations: upper line—4:30 P.M.; and 12 M., 11 P.M. and 6 A.M. respectively for adjacent lines.

pressed as cm. of precipitable water). This curve shows the characteristic dependence of band absorption on the amount of absorbing gas penetrated.

Measurements of Water Vapor Absorption at 21 μ.—The water vapor absorption of the 21 μ residual ray band of quartz was measured using a globar source. The 21 μ residual ray band was obtained by three reflections from quartz and two from MgO. The latter reflections eliminate the 8.8 μ residual rays of quartz. The intensity of the 21 μ energy received was

measured in terms of the 8.8 μ intensity. This expedient, of expressing the 21 μ energy as a ratio, avoids possible errors due to faulty focussing. The 8.8 μ residual rays are known to lie in a position of the spectrum where they are not sensibly attenuated by the amount of water vapor penetrated here.

FIG. 10.



Apophyllite residual ray response produced by sky emission. Observations made at regular intervals from 11 A.M. April 16, 1939 until 7:30 P.M. April 17.

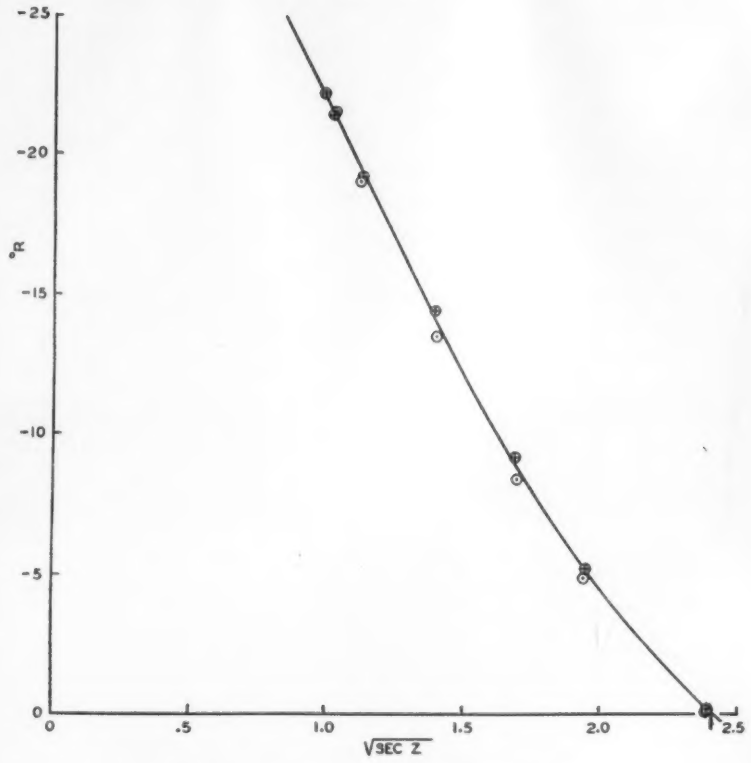
The results of three measurements are plotted, in two manners, in Fig. 8. The absorption involved appears to be of the band type.

For purposes of comparison with Hettner's results for steam, an "average optical density" is determined from the dashed line of Fig. 8. The value obtained is 10 as compared with 50 obtained from Hettner's results [13] by Brunt.[14]

[13] G. Hettner, *Ann d. Phys.*, **55**, 476 (1918).

[14] David Brunt, "Physical and Dynamical Meteorology," *Cambridge University Press*, 1934, p. 102.

FIG. 11.



SiC residual ray response produced by sky emission.

Measurements of Sky Emission.—The radiation temperature of a body may be defined by the equation

$$t_{\circ_R} = 100\,\frac{d_t - d_0}{d_{100} - d_0}, \qquad (2)$$

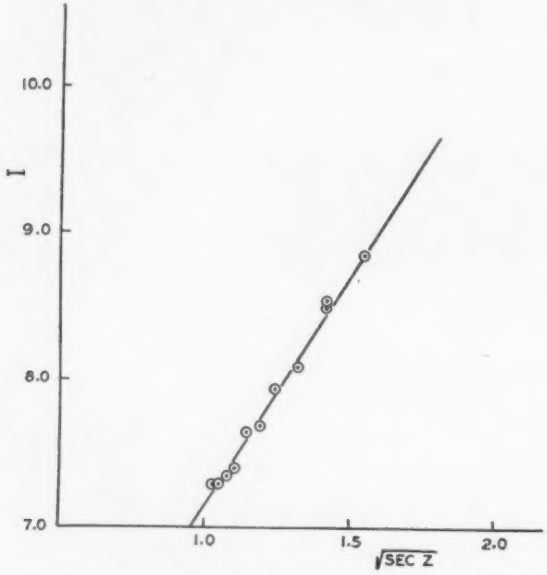
where d_t is the position of the galvanometer spot when a radiation measuring apparatus is trained on the body in question, d_0 is the position of the spot when the apparatus is trained on a black body at 0° C., d_{100} is the position when the apparatus is trained on a black body at 100° C.[15] For ex-

[15] A further discussion of this subject appears in *J. O. S. A.*, **29**, 520 (1939).

ample when the thermometric property is emission at 8.8 μ the scale of temperature is such that absolute cold is $-$ 25.6° R.

Measurements of the effective sky temperature and the sky emission have been made at various zenith distances at 8.8, 9.6, 11.86 and 11.1 μ. These effective sky temperatures are linearly proportional to the energy flux emitted by the sky. In Figs. 9, 10, 11 and 12 these measurements are plotted versus the square root of the zenith distance.

FIG. 12.



K_2CrO_4 residual ray response produced by sky emission. Ordinates are galvanometer deflections.

Figure 9 shows the results obtained with the 8.8 μ residual rays of quartz. The observations were made over a period of several days. Furthermore, they were grouped and averaged for various times of day. The measurements were made at various zenith distances in an interval of time short enough so that the amount of water vapor overhead may be regarded as constant.

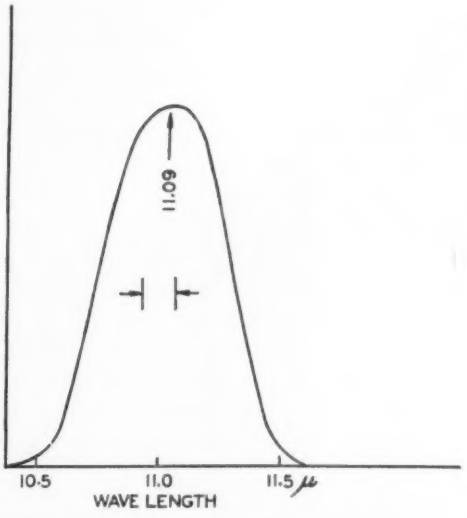
Figure 10 shows the results obtained using the apophyllite residual ray band depicted in Fig. 1. This plot is not as

straight as the others; no doubt due to the emission of atmospheric ozone.

Figure 11 shows results obtained with the 11.86 μ residual ray band.

Figure 12 shows results obtained with the K_2CrO_4 residual ray band. The ordinates here represent the deflection of the galvanometer light spot above its position when the apparatus was trained on liquid air. Under the conditions obtaining when the measurements were taken melting ice produced a deflection of 17.7 m./m. The response band of the K_2CrO_4 residual rays is depicted in Fig. 13.

FIG. 13.



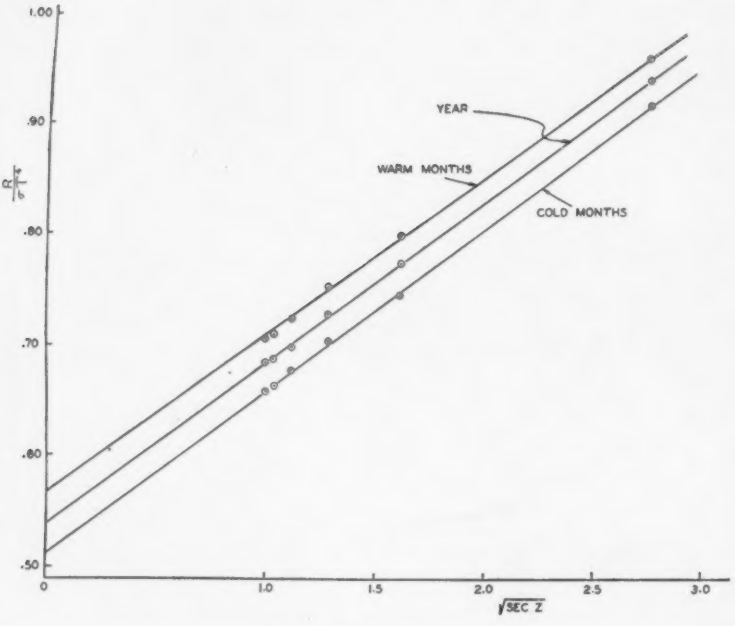
K_2CrO_4 residual ray response.

Total Sky Radiation Measurements of Dines.—The back radiation received from the clear sky by a blackened receiver has been measured as a function of zenith distance by Dines.[16] We will use his results in a further example of the new method of managing such measurements. The energy flux determined by Dines' measurements are divided by the energy flux re-

[16] W. H. Dines and L. H. G. Dines, *Memoirs of the Royal Meteorological Society*, **2**, No. 11, London, 1927.

ceived horizontally and this dimensionless quantity is plotted in Fig. 14, as ordinate, against the square root of the zenith distance, as abscissa. The middle line represents the yearly mean of the results; the two outer lines represent monthly means averaged for the warmest five and coldest seven months

FIG. 14.



Dines observations of total sky emission plotted in the new manner.

of the year. The intercept at "$\sqrt{\sec z} = 0$" is higher for the warmer months.

Brunt's Formula.—It has been shown by Brunt [17] that a formula of the type

$$R = \sigma T^4(a + b\sqrt{e}) \qquad (3)$$

adequately represents the dependence of sky radiation on the surface air temperature, T, as well as on the surface humidity, e. This formula represents both the irradiation from various zones as measured by Dines, and the integrated radiation from

[17] D. Brunt, *Quart. Jour. Roy. Met. Soc.*, **58**, 389 (1933).

the whole sky as determined by Dines and others. e is the vapor pressure of the water vapor expressed in millibars. σ is Stefan's constant.

As the formula applies to Dines' zonal measurements, the empirical constant b, according to Brunt, is the same for all zones while a is different for each zone.

As the formula applies to the radiation integrated over the whole sky, the empirical constants a and b vary with observers (apparently an instrumental variation) and also they vary with locale (apparently a result of different meteorological factors).

It is obvious that Brunt's formula applies only when there exist substantially constant water vapor and temperature distributions overhead; as when the formula is applied to an averaged series of measurements.

A theoretical justification of Brunt's formula has not been heretofore advanced. The main difficulty has been to explain the meaning of the first term. Brunt says, "It is not considered in any way justifiable to interpret its meaning when $e = 0$ as indicating that $a\sigma T^4$ is the radiation from dry air alone. If this were accepted, then the radiation from the dry air would exceed that from the water-vapor in the atmosphere, and all the available evidence points to the falsity of such a supposition."

Explanation of Brunt's Formula.—An explanation of Brunt's formula is here advanced. The straight line of Fig. 14, as well as other considerations, suggests the rewriting of Brunt's formula in a more general form:

$$R_z = a\sigma T^4 + b\sigma T^4\sqrt{e \sec z}. \qquad (4)$$

R_z represents the sky radiation received at zenith distance z. Both terms of Eq. 4 have the form of the emissivity of grey bodies with emissivities respectively a and $b\sqrt{e \sec z}$.

Equation 4 is explained by postulating that the emission of the sky is composed of two contributions. The first term of the formula represents one contribution. This one contribution is, in turn, composed of the emissions at the multiplicity of narrow wavelength intervals which constitute the individual lines of the 6.3 μ oscillation-rotation band of water vapor, the

14.95 μ oscillation-rotation band of CO_2 and the pure rotation band of water vapor centered at 50 μ. Within these narrow wavelength intervals the absorption is complete for a short optical path: a path so short that the effective radiating temperature of the air involved is substantially the same as that of the surface air. The fact that the integrated emission is proportional to that of a black body at the temperature of the surface air and may be represented by a coefficient similar to that representing the emissivity of a grey body is, in one sense, misleading—instead of a uniform low emissivity over the whole heat spectrum involved we have rather a multiplicity of narrow regions of very high emissivity separated by more or less transparent regions. The fact that the integrated emissions may be represented simply by an emissivity-like coefficient signifies that the distribution of these emissions in the heat spectrum is such as to effectively sample that heat spectrum.

The second term of Eq. 4 represents, mainly, the contribution of radiation within the "window." In addition, it represents the contribution at other places in the spectrum where the atmosphere is not opaque. We have already determined that the emission of the sky within the "window" is proportional to $\sqrt{\sec z}$. We may assume that, over a long period of time, the averaged total water vapor penetrated is proportional to the averaged surface humidity.

In the second term of Eq. 4, the coefficient $\sigma\sqrt{e \sec z}$ is more easily explained than the factor σT^4. The most plausible explanation of this factor predicts a fifth rather than fourth power dependence of the second term on temperature. It is a property of black-body emission that the intensity at the maximum is proportional to the fifth power of the absolute temperature and the main fraction of the emission represented by the second term, lying mainly within the "window," is confined in an interval of wavelengths lying near the maxima of all the black-body curves which one may draw for temperatures ranging from 280° K. (ground temperature) to 218° K. (stratosphere temperature).

A statistical study of the old measurements in the light of the present explanation of Brunt's formula may lead to new evaluations of the constants and perhaps to new or revised

terms in the formula. The valuable feature of Brunt's formula is its simplicity and the close agreement between its predictions and observations is apparently significant.

The foregoing explanation of Brunt's formula recalls Simpson's somewhat similar treatment [18] of atmospheric radiation. Simpson divided the heat spectrum into two principal parts: for one, the atmosphere was regarded as being completely opaque; for the other, as being completely transparent. The success of Simpson's analysis of terrestrial emission is support for the significance of his formulation, and in turn, for the explanation of Brunt's formula given here. (Simpson's division of the spectrum necessarily precludes heat transfer by radiation within the atmosphere and accounts only for heat transfer to and from the atmosphere at its lower and upper boundaries.)

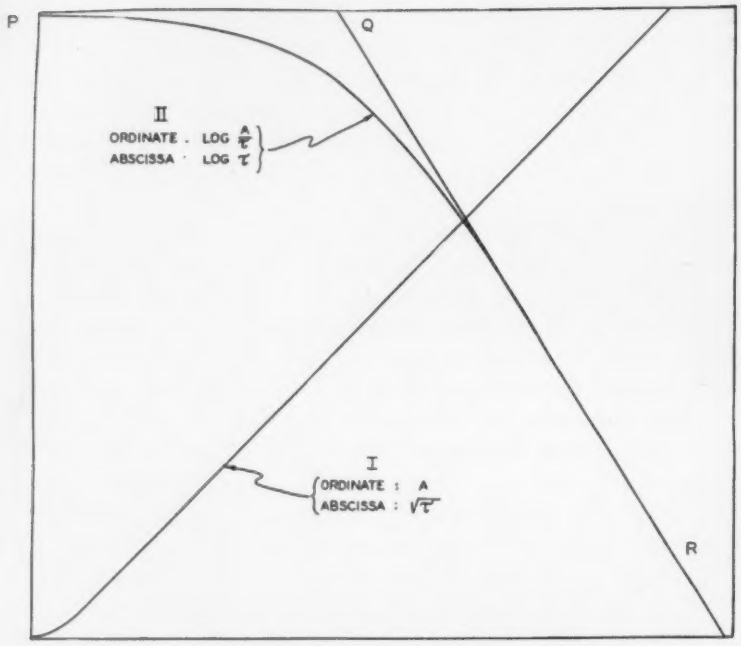
Dr. Elsasser has recently measured the emission of various columns of the atmosphere bounded by a liquid-air-temperature black-body as a background. He finds that a column containing one third of a centimeter of precipitable water vapor has an effective emissivity vapor of approximately 0.5. For a sea level station this amount of water vapor is contained in a vertical column of only a few hundred feet in height.

The first term in Brunt's formula, the radiation $a\sigma T^4$, obtained by setting $\sqrt{e} = 0$, is therefore not to be interpreted as the radiation from dry air alone but rather it is to be interpreted as the radiation from the individual spectral lines of water vapor and carbon dioxide within which the absorption is high enough, even on the driest days, to make opaque the bottom layer of the atmosphere near the surface. Where the effective temperature may be taken as substantially equal to the surface air temperature. In this connection it is interesting to note that in Fig. 14 the intercept is higher for the warm months than for the cold months. This is what one would expect. The vertical column of air necessary for opacity, small in either case, is greater during the cold months. The effective radiation temperature during the cold months is depressed below the surface temperature by a greater amount than when the temperature and humidity are higher.

[18] G. C. Simpson, *Memoirs of Roy. Met. Soc.*, **3**, No. 21, 1928.

The Integrated Transmission of Water Vapor.—A formula for the sky radiation received at the surface of the earth, taking account of a particular obtaining vertical distribution of water vapor and temperature (which Brunt's formula does not take account of), will involve as an empirical basic function; the dependence of the total emission on the amount of water

FIG. 15.



Diagrammatic representation of Matheson's observations of absorption by the 4.66μ CO band.

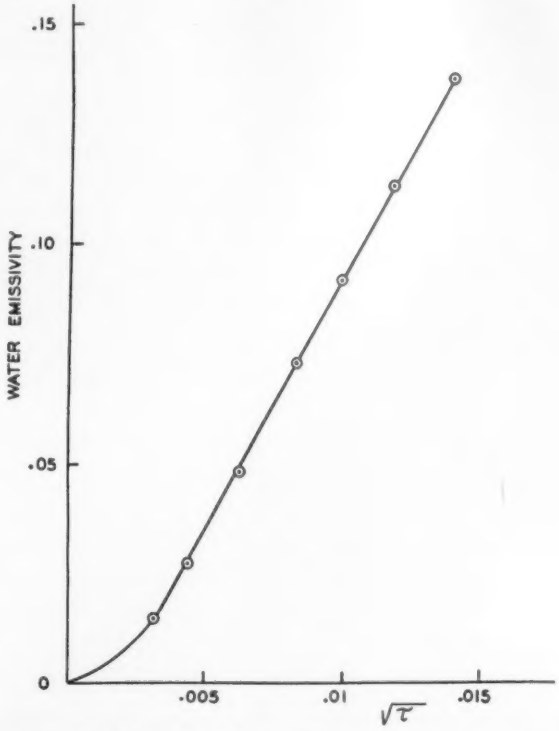
penetrated. This basic function will correspond to uniform physical conditions—say a uniform temperature of the water vapor of 0° C. and a uniform total pressure of one atmosphere. The determination of such an empirical function has been the object of investigations by Elsasser [19] and others. The mathematical representation of the total (or spectral) emission, and the adaptation of it to the varying temperatures and pressures

[19] W. M. Elsasser, Meeting of the American Physical Society, Pasadena, December, 1940.

obtaining overhead in the atmosphere will be facilitated if we review our knowledge of band absorption.

Figure 15 shows diagramatically, the dependence of absorption by the CO band at 4.66 μ on the amount of gas

FIG. 16.



Emissivity of air at 15° C. (dew point 0° C.) plotted against square root of water vapor penetrated. The measurements represented here, made by F. A. Brooks of the University of California and H. C. Hottel of Massachusetts Institute of Technology, were privately communicated. They were made viewing, as a background, a *kohlraum* chilled by liquid nitrogen.

penetrated.[20] Absorption is plotted as ordinate and the square root of the amount of gas penetrated as abscissa (Curve I). The data used for this plot, taken from Matheson's Fig. 8, are represented in Fig. 15 by Curve II. In Matheson's diagram the logarithm of the absorption divided by the amount of gas penetrated is plotted as ordinate while

[20] Lorne A. Matheson, *Phys. Rev.*, **40**, 813 (1932).

the logarithm of the amount of gas penetrated is plotted as abscissa. There are two "asymptotes" to this curve; the horizontal line PQ representing a Beer's law dependence on amount of gas penetrated, and the line QR having a slope of $-\frac{1}{2}$ representing the ordinary square root dependence exhibited by band absorption.

Curve I exhibits an intercept at $A = 0$. The existence of such an intercept is also indicated in some of the sky emission plots and in Fig. 16.

The square root dependence of absorption cannot hold for all thicknesses of gas penetrated—the maximum value the absorption can have is unity. The absorption must therefore deviate from the square root dependence when sufficiently great amounts of gas are penetrated. Elsasser has developed a formula which is equivalent to the square root dependence for the smaller amounts of gas penetrated and which holds for larger amounts penetrated:

$$A = \phi(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-x^2} dx, \tag{5}$$

where $x = k\sqrt{\tau}$.

It is suggested that the empirical basic function for the total emission of water vapor may be best represented as square root terms rather than as a series of exponential terms in τ. (Brunt's formula is such an expression in which there are two terms.) Figure 16 shows data for the emission of water vapor [21] plotted in the new manner as a function of $\sqrt{\tau}$.

[21] The water emission data was privately communicated to the author by F. A. Brooks.

SOME OBSERVATIONS ON ELECTRICAL DISCHARGES FROM POINTED CONDUCTORS.

BY

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GENERAL PROPERTIES.

In electrical discharges through gases between a point and a plane, owing to the highly divergent character of the field between the two electrodes, any multiplication of such ions as are produced in the field by outside agencies is confined mainly to the neighborhood of the point, as long as the applied voltage is not far above that required to start the discharge. The ions in the space between the plane and the active region near the point are, therefore, predominantly of the same sign as the charge on the point. The space charge resulting from these ions alters the field in such a way that near the point the field is weakened, and in consequence a limit is set upon the rate of generation of new ions in this region by the collision of electrons with neutral molecules. In other places where the space charge strengthens the field the value of the field remains too low for the production of new ions by collision.

Nevertheless, the ions are not entirely of one sign even in the neighborhood of the plane itself. The presence at some distance from the point of a relatively small number of ions, opposite in sign to the charge on the point, was first demonstrated by C. T. R. Wilson [1] by means of his cloud chamber. Later, by the aid of a probe, the number of these ions was found [2] to increase rapidly with the strength of the current flowing and to increase also as the gas pressure was reduced. Such ions are probably produced in the gas by photo-ionization, the photons coming from the active region near the point. When the point is charged positively, some electron emission from the plane electrode is also indicated,

[1] C. T. R. Wilson, *Phil. Trans.*, **192**, 403 (1899).

[2] J. Zeleny, *Phys. Rev.*, **33**, 70 (1911).

since in that case the number of negative ions present in the gas was found to be larger than the number of positive ions under like conditions when the point was charged negatively.

The general effect of the space charge upon the field between the plane and the active region near the point is to make the field more uniform than it is when no current is flowing. For equal currents the potential gradient at any place is larger when positive ions are moving toward the plane than it is with negative ions, and the ratio of the gradients for the two discharges was found [3] to be nearly inversely proportional to the mobilities of the two kinds of ions involved. Accordingly, under the condition of equal currents, the actual velocities of the two ions must be nearly equal at corresponding points in the two kinds of discharges, and hence the charge densities at such points must also be nearly equal. This follows because the current per square centimeter at any point is

$$i = nekX,$$

where n is the ion density, e the charge on each ion, k its mobility, and X the strength of the field at the point in question. Then if for equal currents in the two discharges the velocities, kX, of the ions are equal, the densities, n, must also be equal, for the results given by Warburg [4] show that under the circumstances presupposed the distributions of the two currents over a cross-section are nearly alike.

It follows, too, that the rate of increase of current with increase of applied voltage should depend upon the mobility of the ions concerned, being larger when the mobility is higher. And experiment shows [5] that curves giving the rise of current with increase of voltage are steeper for negative point discharges than for positive discharges.

For both discharges these curves become more steep as the pressure of the gas is reduced.

Such curves are also steeper for large sized points than they are for smaller points, since, owing to the larger potentials required to start the discharge from the larger points,

[3] O. Hovda, *Phys. Rev.*, **34**, 25 (1912).
[4] E. Warburg, *Wied. Ann.*, **67**, 69 (1899).
[5] J. Zeleny, *Phys. Rev.*, **25**, 305 (1907).

the velocities of the ions for any given current are higher and hence the space charges are smaller.

The current-voltage curves become less steep as the distance between the point and the plane is increased,[3] owing to the greater length over which the current-repressing space charge extends.

That nearly all of the voltage which is applied to a point, above that needed to start the discharge, is required for moving the ions across the low field portion of the inter-electrode space rather than for the increased production of ions near the point itself is attested by the experimental findings [6] that during a discharge the strength of the field at the surface of a given point remains almost constant for a several-fold increase in the applied voltage. However, to produce the added supply of ions the ionizing field must extend a little farther into the gas whenever the potential of the point is increased.

The field at the surface of a point during a discharge is actually smaller when the radius of curvature of the point used is large than when it is small, although the potential required to start the discharge is naturally greater for the larger point. An explanation of this fact has already been given,[7] and was based on the more rapid diminution of the field with distance from its surface for the point having the smaller radius of curvature. The volume in which new ions are formed by the collision process is therefore smaller for a small point than it is for a larger point when the fields at their surfaces are alike, and hence to produce a given number of ions the smaller point requires a stronger field.

During some work [8] in which the pointed electrode was placed 30 cm. or more from the plane, it was often noted that when the positive corona discharge, characterized by an extended thin luminous coat of light at the surface of the electrode, suddenly changed to the brush form of discharge, which consisted of a short pencil of light at the electrode from whose free end a wide brush spread out abruptly which was

[6] A. P. Chattock, *Phil. Mag.*, **32**, 285 (1891); **20**, 266 (1910); J. Zeleny, *Phys. Rev.*, **3**, 69 (1914); **16**, 102 (1920).

[7] Last reference under 6, p. 121.

[8] J. Zeleny, J. FRANK. INST., **218**, 685 (1934).

made up of a large number of luminous filaments about 10 cm. long, not the slightest change in the magnitude of the current flowing was observed. The space charge limitation on the strength of the current was not affected here by even this large change in the form of the discharge. However, there were exceptions to this behavior when a substantial increase in the current accompanied what appeared to be the same change in the form of the discharge as that just described.

Positive brush discharges from points were found to change into spark discharges at much lower voltages than did negative discharges.

It is also of interest to note that when large distances were used between a point and a plane, which permitted currents of the order of a quarter of a milliampere to flow before sparking occurred, the values of the currents obtained when the same high voltage was applied to different sized points ranging from a sharp sewing needle to a cylindrical rod 5 mm. in diameter, owing to space charge regulation, were found to be roughly independent of the size of the point used, although the potentials at which the discharges from these points began differed greatly. Thus, contrary to common belief, the efficiency of a lightning rod for effectively extending its length by producing a conducting path in the air above it, owing to the high fields prevailing, depends but little upon the sharpness of its pointed end.

CURRENT-VOLTAGE RELATIONS.

In early work on point discharges little attempt was made to specify the sharpness of the points used, and none of the results obtained with such points could be numerically reproduced by other experimenters. Warburg [4] found, however, that for any given point the currents, I, obtained by applying different voltages, V, can be represented by the formula

$$I = aV(V - M),$$

where, a is a constant depending upon the nature of the point and other factors, and M is the potential required to start a discharge from the point under the given circumstances. Later it was found [9] that points having shapes that are easily

[9] J. Zeleny, *Phys. Rev.*, **25**, 305 (1907); **26**, 129 (1908).

defined can be constructed which give reproducible results. The simplest shape was found to be a cylindrical wire having a rounded end, and this form has been generally adopted by later observers. Considerable deviation from sphericity in the end of the point does not influence appreciably the magnitude of the current obtained with a given applied voltage, and the material of which the point is made is also of very little, if any, practical importance.[10]

For a given distance between point and plane the constants a and M in Warburg's formula were found to be simple functions solely of the diameter of the point used. While the formula was found to represent very well the current-voltage relations for positive discharges from a great variety of points with plate distances of 1 and 1.5 cm., which alone were used, it did not apply to negative discharges at all well, perhaps because these discharges in air were apt to be intermittent and less steady.

The processes participating in discharges from points are complicated and not well enough known to permit the derivation of the constants of any formula relating the current to the applied voltage.

ANOMALOUS BEHAVIOR NEAR STARTING POTENTIALS.

While the current-voltage relations of the discharges from points are in general reproducible with a fair degree of accuracy for currents above a few microamperes, the initial stages of these discharges very often show an erratic behavior. The current is apt to begin with irregular, discrete, impulsive discharges [11] at a voltage which for a given point may depend greatly upon the previous treatment of the point surface, indicating that some variable condition of this surface, be it a resistance or the work function, plays an important role in the functioning of the point. The first few of these impulsive discharges may occur at lower voltages than the succeeding ones and the voltage at which a self-sustained discharge sets in is often quite variable. A part of this variability arises

[10] J. Zeleny, *Phys. Rev.*, **16**, 123 (1920); O. Hovda, Inaugural Dissertation Goettingen (1913).

[11] W. C. Roentgen, *Goett. Nachricht.*, **34**, 390 (1878); F. Tamm, *Ann. d. Physik*, **6**, 529 (1901); G. R. Gorton and E. Warburg, *Ann. d. Physik*, **18**, 128 (1905).

from the fact that the discharge is initiated by the entry into the field of the point of ionizing entities which have a fortuitous time distribution so that the rate at which the voltage is raised determines in part the value found for it at which the current starts. After a discharge has been started the potential of the point may be reduced below its starting value before the current will break.

At times a certain behavior of a given point which readily repeats itself on one day can be reproduced with great difficulty, if at all, at a later time.[12]

The initial stages of negative discharges are usually much more erratic than are those of positive discharges from the same points, and after use the currents for voltages near the starting potential are wont to be much smaller than they were when the discharge was first started.[13]

The negative currents usually start with irregularly spaced, discrete discharges and as the voltage is raised these change to a regular intermittence so that a telephone receiver in the circuit gives a clear note whose pitch rises steadily as the current is increased and has been followed to the limit of audition.[14] However, at times, a telephone receiver in the circuit showed no intermittence for the smaller negative currents and such intermittence only appeared when the higher currents were reached, and the opposite behavior has also been observed where currents intermittent at low values became steady at high values. In other cases a string galvanometer in circuit indicated the presence of an intermittent component superimposed upon a much larger steady current. Occasionally, too, both positive and negative discharge currents have been followed down to values as low as 10^{-9} amperes which gave a steady deflection on a galvanometer and for which a sensitive telephone receiver in the circuit gave no response.[15]

Recently, Trichel,[16] by means of a cathode ray oscillograph, has observed discrete current pulses in negative dis-

[12] First reference under 10, p. 106.

[13] J. Zeleny, *Phys. Rev.*, **26**, 135 (1908).

[14] Reference 5, p. 310.

[15] J. Zeleny, *Phys. Rev.*, **24**, 258 (1924).

[16] G. W. Trichel, *Phys. Rev.*, **54**, 1078 (1938).

charges in air having frequencies of over 200,000 per second. It appears from the oscillograms published that the times between the separate bursts of current are not quite all equal. Trichel ascribes the interruptions or sudden decreases in the current to a temporary weakening of the field between the plane and the active region near the point, this weakening being due to the positive space charge left near the point following a sudden production of ions there, after the electrons have rapidly moved away. The current is supposed to remain interrupted while the positive ions are moving the short distance to the surface of the point. Although this theory, so briefly outlined, accounts qualitatively for the independence of the frequency of intermittence of the inter-electrode distance and for its decrease with increase in size of the point used, it is nevertheless not evident why on this view this frequency should increase with the magnitude of the current, since the field at the point is independent of the current.

In positive discharges the impulsive currents, which usually precede the appearance of the continuous corona discharge, appear as narrow streamers which extend a short distance (at times a considerable distance) beyond the corona limit. They are accompanied by specks of light on the anode surface. Sometimes these streamers appear superimposed upon the corona but it has not been determined whether the two forms are actually simultaneous or only seem to be so to the eye. It may be significant that when a corona current is gradually decreased toward zero, just as it breaks, a few streamers of the same kind as were observed at the beginning of the discharge flash into view. Similar effects on a more spectacular scale have been observed with point discharges in air at reduced pressures where small currents cannot be maintained and the discharges always start impulsively.[17] Here the discharge started with a flash of light that extended from a bright spot on the point almost to the plate which itself was partly covered with a luminous glow. After this flash the discharge assumed the characteristic corona form with light covering the point anode alone. It almost seemed as if the flash of light represented the removal of some re-

[17] Reference 13, p. 149.

sistance that had to be annulled before the corona discharge could start. However, as the voltage was now reduced the current ended suddenly, surprisingly enough, with another bright flash just like the one seen at the beginning, as if the corona form of discharge could not maintain itself below a certain value of the current whereas the other form could do so.

GEIGER COUNTERS.

Points are sometimes found by accident, or produced by a special surface treatment that does not alter their shape, which for prolonged periods of time do not give the initial erratic bursts of current that have been described, and exhibit the property that for them there is an exceptionally large range of voltages between the lowest one sufficient to start a self-sustained discharge and the smallest one that can maintain the current once it has been started.[20] Such points are used in Geiger counters [18] because for them there is a fairly definite range of voltages [19] where the entrance of each ionizing entity into a limited volume gives rise to a momentary and easily detectable current. There is at present no unanimity of opinion as to how a point counter functions nor as to what gives a surface the property essential for a reliable counter.

According to one view [20] the point should have a uniform layer of gas molecules adhering to its surface which prevents ions from discharging themselves readily so that a surface charge can be built up which reduces the interelectrode field and stops the discharge.

Others maintain that photo-ionization and the emission of electrons by positive ion impact play the leading roles, and these argue that what is most important in a Geiger-Mueller counter, which consists essentially of a fine wire stretched along the axis of a cylinder, is that the work function have the same value over the whole surface of the cathode, so that the response of the counter will be independent of the place of entry of the ionizing particles which are to be counted.

[18] H. Geiger, *Verh. D. Phys. Ges.*, **15**, 534 (1913).

[19] Geiger Counter Range adequately describes this region. Loeb's introduction here of a new term "regime" seems unnecessary, and rather stretches the usual connotation of the word.

[20] J. Zeleny, *Phys. Rev.*, **19**, 566 (1922); H. Geiger, *Zeit. f. Physik*, **27**, 7 (1924).

The interruption of the current in these counters, where the wire is the anode, has been ascribed [21] to the effect of the positive space charge arising from ions formed near the wire, which weakens the field in this active region during the whole time that this space charge is moving over to the cathode.

A high resistance placed in series with a point also serves to reduce the field as soon as a discharge begins, as it enables a charge to build up on the point.

Counters at times give spurious counts following close upon a real count, and Paetow [22] accounts for these by supposing them due to a delayed field emission of electrons from the metal, which is caused by the intense field arising from ions accumulated during the real count upon some non-conducting material adhering to the surface of the cathode. Possibly some of the erratic behavior in the initial stages of discharges from points may have a similar explanation.

The various ideas mentioned above are not necessarily mutually exclusive and their relative importance may well differ under different circumstances.

APPEARANCE OF DISCHARGES.

The typical positive and negative discharges look altogether different. The positive corona discharge and the positive brush discharge, into which the corona form changes at higher currents, have already been described sufficiently above. (For sketches see J. Zeleny, *Phys. Rev.*, **3**, 77, 1914.)

The negative discharge consists of a short stubby brush of light whose length depends upon the diameter of the point and is always less than that of the positive brush. The small area of the surface from which the negative discharge starts is some preferred area which is not necessarily situated at the tip end of the point where the field is the strongest, and its position does not always remain fixed. At voltages well above the starting potential, and especially with the larger sized points, a number of brushes appear to be present at the same time but in such cases short exposure photographs showed but one brush [23] proving that the multiple appearance

[21] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **57**, 1030 (1940).

[22] H. Paetow, *Zeit. f. Physik*, 111, 770 (1939).

[23] Reference 8, p. 687.

was due to the jumping about of a single discharge. It has been suggested that the work function of a surface is perhaps augmented by the action of a strong discharge current and that therefore the brush keeps moving to new areas having a lower work function, the presence of a process being presupposed which involves a liberation of electrons from the surface either by photoelectric action or by collision of positive ions.

Microscopic examination of the negative brush and microphotographs of it show that even at atmospheric pressure the brush has all of the main features found near the cathode in glow discharges at low pressures.[24] Thus, starting at the surface of the point, there are seen in order the Crookes dark space, the negative glow and the Faraday dark space, and finally the brush itself takes the part of the positive column. When the pressure of the gas around the point was reduced these various regions expanded regularly so that the designation given to them is unmistakably a correct one.

Measurements of the length of the Crookes dark space in several gases showed this length to vary inversely as the pressure of the gas. The conditions for these measurements were found to be especially favorable in helium.

CURRENT-VOLTAGE CHARACTERISTICS IN INITIAL STAGES OF POSITIVE DISCHARGES.

Trichel [25] made the interesting discovery that positive discharge currents in air and hydrogen, but not in nitrogen, when studied with a cathode-ray oscillograph, show irregular high frequency variations of magnitude which may be as large as five per cent of the total current; and because of these variations he postulates that the corona discharge consists of a very rapid succession of random burst discharges, the light from which to the eye gives the impression of continuity.

Kip [26] has extended these oscillographic studies to the initial stages of positive currents from points and found that in this region the discharges consist of isolated bursts the

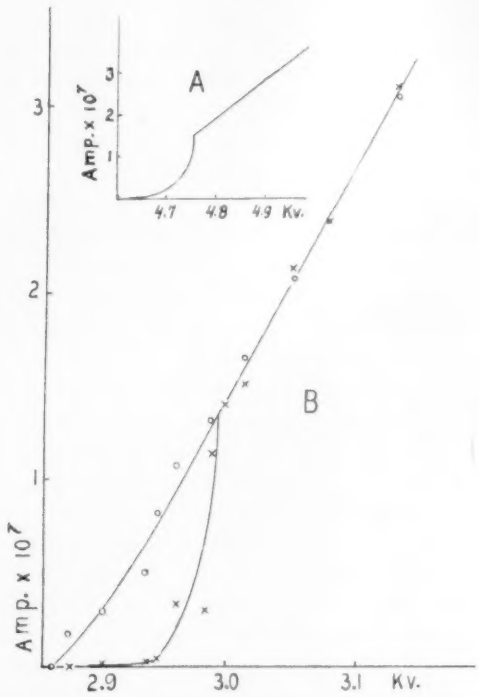
[24] J. Zeleny, *Phys. Rev.*, **24**, 269 (1924). Recently Trichel, reference 16, has also observed these characteristics.

[25] G. W. Trichel, *Phys. Rev.*, **55**, 382 (1939).

[26] A. F. Kip, *Phys. Rev.*, **55**, 549 (1939).

duration of each of which increases and the time interval between them decreases as the voltage is raised. The current in each burst showed the same kind of fluctuations as are found at higher voltages when the current appears continuous. The current measurements were all made with a galvanometer

FIG. 1.



Current-voltage relation near onset of positive discharges. *A*. Curve given by Loeb and Kip. *B*. New results. Circles represent peak current readings with oscillograph; crosses, galvanometer readings of the same currents.

only, and Loeb and Kip [27] picture the results in a curve which shows the variations of the initial stages of the current with the applied voltage.

This curve is reproduced as insert *A* in Fig. 1, and is seen to consist of two distinct parts having quite different characteristics. The current at first rises very slowly with increase

[27] L. B. Loeb and A. F. Kip, *J. App. Phys.*, **10**, 150 (1939).

of voltage and then goes up very rapidly to a discontinuity, after which the rise is more gradual and more uniform.

In order to learn whether the law of increase of current with voltage actually changes thus abruptly in passing from one of these regions to the other, I had my assistant, Dr. J. R. Dietrich, make some measurements of the magnitudes of the currents in the isolated pulses present at the start of the discharge.

The point used was a platinum wire of 0.17 mm. diameter with a rounded end. It was placed 10.2 mm. from a plane electrode in a vessel containing dry air at atmospheric pressure. The currents were measured both with a directly connected, calibrated DuMont oscillograph and with a sensitive galvanometer. Since the oscillograph readings showed the zigzag variations in magnitude described above, the peak values of the current in each burst were used for plotting on curve *B* in Fig. 1. These oscillograph readings are shown by circles and the corresponding galvanometer readings by crosses. The peak values of the pulse currents registered on the oscillograph are seen to lie on a continuous curve with the points for currents above the discontinuity found in the galvanometer curve, showing that these momentary currents are subject to the same space charge limitations as would obtain were the currents continuous.

Results of the same character were also obtained for positive discharges in air at 60 mm. pressure between a long wire of 0.07 mm. diameter and a coaxial cylinder of 22 mm. diameter.

It is thus evident that the sudden change in characteristic shown in Loeb and Kip's curve *A* indicates nothing more than that below the point of discontinuity the galvanometer used to measure the current simply gave an average of an intermittent current which was interrupted a smaller and smaller fraction of the time as the voltage was increased.

EFFECTS OF ARTIFICIAL IONIZING SOURCES ON POINT DISCHARGES.

As has already been mentioned a retardation is usually observed in the starting of discharges from points, so that the current starts impulsively with a value of several microamperes and then on reduction of the voltage also stops suddenly.

Gorton and Warburg found [28] that a radioactive substance placed near by, which produces a more or less continuous supply of ions in the critical volume near the point, wholly or in large part eliminates the retardation of the discharge.

With the weak radioactive sources usually employed for this purpose the ions supplied have to be multiplied very greatly before the current produced by them can be detected on a sensitive galvanometer, and it is not possible to tell at what voltage the collision processes begin to produce new ions and how rapidly the multiplication of ions proceeds as the voltage is raised.

In order to study these relations some experiments were carried out [29] in which a radioactive source so strong was used that the ions produced by it alone, before any multiplication of them by the field, gave a current between the point and plane that could easily be measured by a galvanometer and at times was used at values as high as 5×10^{-9} amperes.

It was found that with a positively charged point 0.39 mm. in diameter placed 1.5 cm. from a plane, to take one example, the ion current in air at 76 cm. pressure began to increase above its saturation value at a potential 2000 volts below the 5000 volts at which the discharge current started in the absence of the radioactive source. The lowest field at the surface of the point for which the ions formed near the point by the radioactive material began to increase in number owing to a collision process was thus about 94,000 volts/cm., as computed by a method previously given,[30] on the supposition that the space charge is still without material effect.

The ion current increased very gradually at first with rise of voltage and then more and more rapidly until at the potential at which the discharge normally began the original ion current had been multiplied about a hundredfold. Since, in the absence of the special radioactive source, the ions must ordinarily be multiplied nearly a millionfold before the current produced by them can be detected on a sensitive galvanometer, then in the experiments under consideration the space charge must already have had a large effect in reducing the current

[28] Reference 11, last item.

[29] J. Zeleny, *Phys. Rev.*, **24**, 262 (1924).

[30] J. Zeleny, *Phys. Rev.*, **3**, 74 (1914).

at the normal starting potential. It is quite probable that it had some effect even at the much lower voltage at which the saturated ion current first began to increase owing to ionization by collision.

Although by bringing up a strong radioactive source a current of hundreds of microamperes could be made to flow at voltages just below the minimum starting potential the current ceased altogether as soon as the material was removed. On the other hand when the minimum starting potential was exceeded the current continued to flow after the removal of the radioactive source, but it dropped to the value it would normally have had in the absence of such a source. This shows that for these small currents, at least, the magnitude of the current is not controlled solely by space charge effects because were that the case it might have been expected that the current for any given voltage would be independent of the method of production of the ions, be it by an outside radioactive source or by a collision process.

Turning now to a negatively charged point, it was found that here the saturation current due to the ions produced by the radioactive source remained practically unchanged as the potential of the point was raised until this reached a certain value, at which the current increased rather suddenly by a factor of a hundred or more. The voltage at which this sudden increase of current occurred depended upon the number of ions introduced, being in the example cited above almost 400 volts below the normal starting potential, which here too was 5000 volts, when the saturation current for the ions introduced was 5×10^{-9} amperes.

The marked difference between the ways in which the current, due to ions supplied from the outside, grows with increase of the applied voltage for the two kinds of discharges may be explained as follows. Electrons (perhaps in part those dissociated by the field from negative ions) on approaching a positively charged point first begin to ionize molecules of the gas only when they get very near to the surface of the point where the field is most intense. As the field is raised the volume in which this ionization can take place increases gradually and so the enhanced ion current also grows slowly

at first and then more and more rapidly as the voltage of the point is raised, as was observed.

With a negatively charged point, on the other hand, the positive ions approaching the point can ionize molecules of the gas only very rarely, if at all. Their impact with the electrode, however, releases electrons which do ionize the gas, giving rise to more electrons and more positive ions which latter in turn cause the emission of still more electrons, and by this process of multiplication the current rapidly grows to a value limited by space charge considerations.

The collision process which has been described above as being responsible for the growth of the ion current when the point was charged positively is probably the sole agent for the increase of ions only in the initial stages of the current growth, and it is possible that even here photoionization plays some part. But owing to the smaller probability of such ionization it is unlikely that in this region it plays the important role that Kip[31] assigns to it in positive discharges in general, where according to his view there is an electron avalanche process similar to that postulated in the positive leader strokes in lightning.

[31] A. F. Kip, *Phys. Rev.*, **54**, 142 (1938).

Estimates of Depth to Bedrock at Dam Sites in the Gunnison, Little Colorado, and Zuni River Basins.—A preliminary report giving the results of geophysical studies made by H. CECIL SPICER to determine the depth to bedrock at 16 dam and reservoir sites in Colorado and Arizona has been released by the Conservation Branch of the Geological Survey, United States Department of Interior. Of the sites in Colorado six are on the East River and the Gunnison River and four are on the Lake Fork of the Gunnison. Of the sites in Arizona five are on the Little Colorado River and one on the Zuni River. The Gish-Rooney electrical resistivity apparatus was used in making the observations, and the report includes a brief description of the procedure. By means of this apparatus a measured electric current is passed into the earth through two metallic stakes driven into the ground, and the voltage is measured at the same time by an instrument connected across two stakes located at equal distances between the current-carrying stakes. A special formula is used to compute from the current and the voltage measured what is called the "apparent electrical resistance" of the volume of earth lying beneath the stakes at which the voltage was read, or in other words, the resistance offered by the earth to the flow of an electric current. A series of such observations are then made with the distance between the stakes increased by regular intervals so that the electric current will penetrate deeper into the earth, and the calculated results are plotted on graph paper. The curve thus formed indicates the character of the geologic materials below the surface of the earth, and the depth to the underlying material is related to the distance between the stakes. The report on each of the dam sites investigated includes an estimate of the thickness of the geologic formations above the bedrock, an estimate of the character of the bedrock along the axis of the proposed dam, and a map of the area adjacent to the site showing the topography and geology and the places where observations were made.

R. H. O.

OVERHEAD BY-PASS GAS PIPE SYSTEM.

BY

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DESCRIPTION OF STRUCTURE.

Prior to the construction of a subway, tunnel, or similar underground improvement in a large city, it is necessary to take care of possible danger from explosions resulting from leaks in the gas mains. Under no condition are existing gas mains in the immediate vicinity permitted to remain buried below the street surface, during the construction work of this nature. The hazard from a mixture of gas and air being ignited by sparks from traffic or transportation systems, lighted matches, sparks from construction equipment and from blasting, makes it necessary to expend considerable sums of money in the form of socalled gas by-passes.

Prior to the practice of eliminating such hazard, explosions of gas mains during construction work did occur. The most serious and noteworthy of these was an explosion in Boston on March 4, 1897, during the construction of the subway at Roylston and Tremont Streets, resulting in the loss of ten lives in addition to property damage of about one million dollars, and no end of accident claims, and more recently an explosion on March 8, 1914, at 23rd Street and 5th Avenue in Manhattan, New York City, indirectly caused by subway construction.

Recent practice requires that all gas mains below the street surface be vacated, or "killed" and replaced either by an overhead line or a pipe at the curb, properly exposed or ventilated to the exterior air. Normally, these pipe lines are carried on each side of the street, and all house connections are made above the street surface. To provide circulation between the by-pass lines on the two sides of the street, it is necessary to connect these two independent lines. The excavation work prevents such lines at the street surface. The

usual procedure is to provide what is known as an overhead gas by-pass, or a pipe line running sufficiently above the street surface to give clearance for traffic, and connected to the existing gas lines, as well as the gas by-pass lines on each side of the street, at such points outside of the excavation limits as will not be affected by the excavation.

During the construction of the subway lines in New York City, such overhead gas by-pass connections are normally about one-half mile apart. In the construction of the Sixth Avenue subway, a distance of slightly over two miles, six overhead by-pass lines have been provided.

The overhead by-pass described in this article was located on the south side of 46th Street crossing 6th Avenue, in the Borough of Manhattan, City of New York. This by-pass is typical of latest practice in this type of construction, although it is the first of this type ever designed and built. The design is applicable to similar work as well as stream and street crossings for any type of pipe carrier.

In the subway construction in New York City since 1925, the average cost of gas by-pass per mile of subway was $127,000. In certain locations, this cost is greatly exceeded, as for instance, on 8th Avenue the by-passing for a distance of one mile in the neighborhood of 34th Street cost $400,000. The approximate cost of by-passing has averaged 2 per cent. of the total cost of subway construction. The cost of the overhead gas by-pass connections has ranged from 10 to 20 per cent. of the total gas by-pass cost included in each contract.

In designing and constructing an overhead gas by-pass, safety of the construction together with a reduction in upkeep costs must be the main consideration. Exposed as it is to possibility of damage from construction work, located usually in an area heavily populated, together with traffic hazard, an accident resulting from failure of a gas by-pass system can cost an unknown amount of damage to life and property. At the same time, the gas by-pass system normally exists during the life of a construction job; in the case of the subway section 3 to 5 years. Materials employed should be such, that upkeep is reduced to a minimum, chiefly because of the danger resulting from a deteriorated structure when upkeep is not easily taken care of.

USUAL DESIGNS AND COSTS.

For overhead gas by-pass systems which occur in the middle of the block, it was customary to install timber or steel truss bridges for carrying the pipe. Where, as is most common, the overhead gas by-pass system occurs at a street intersection, the usual construction is a suspension bridge with towers located so that their foundations will not be affected by the subway excavation, and with steel cable hangers and back stays. The back stays normally are anchored into concrete blocks built below the street surface. In this type of construction, the towers were formerly made of timber, but more recently they are of steel. The gas pipe itself is steel and the chief problem concerns the type of joints. Up to the design described in this paper, the usual joint was either Dresser couplings or a riveted joint. In a

FIG. A.

48" Gas pipe at 127th St. over St. Nicholas Ave., New York (1925) with riveted joints.

FIG. *B*.

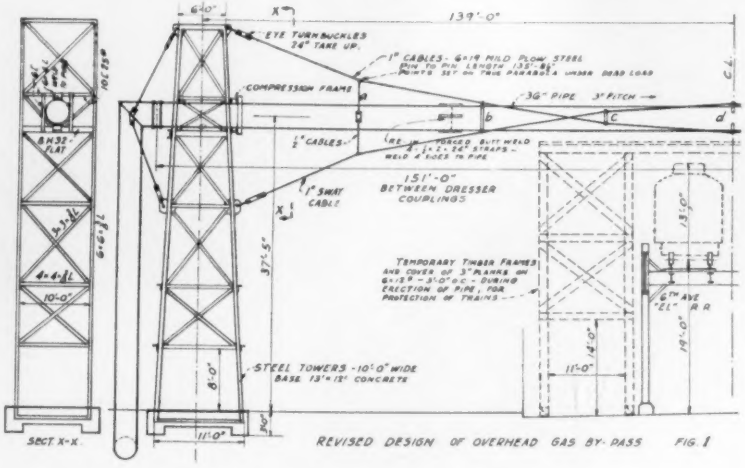
24″ Gas pipe with sleeve and dresser couplings at 29th St. over 8th Avenue, New York (1926). Note sag in pipe line at coupling.

number of instances, welded joints have been tried, but the chief objection had been the deflection of the pipe, due to the flexibility of the suspended type of construction, causing openings in the welds. In addition, there has been considerable objection to the back stays of the towers, because of the obstruction to cross traffic and the great danger of people tripping or running into these obstructions on the sidewalks.

The average cost of the usual type of construction has run from $30 to $60 per foot of structural support for the gas pipe, in addition to payment for the cost of the gas pipe itself. The size of gas pipes so hung above the street surface has varied from 16″ to 48″ depending upon the size of gas lines existing in the neighborhood.

DESIGN OF THIS STRUCTURE

As part of the contract for Route 101, Section 10 Subway (Sixth Avenue between 40th and 47 Streets, New York), the contract provided for a 36″ overhead gas by-pass of the usual type of suspension system, the pipe placed approximately 36 feet above the street surface, to provide clearance for the elevated railroad trains in 6th Avenue, to be located in 46th Street.



The Contractor felt that a revision in design would be advisable because of the following objections to the type shown in the contract:

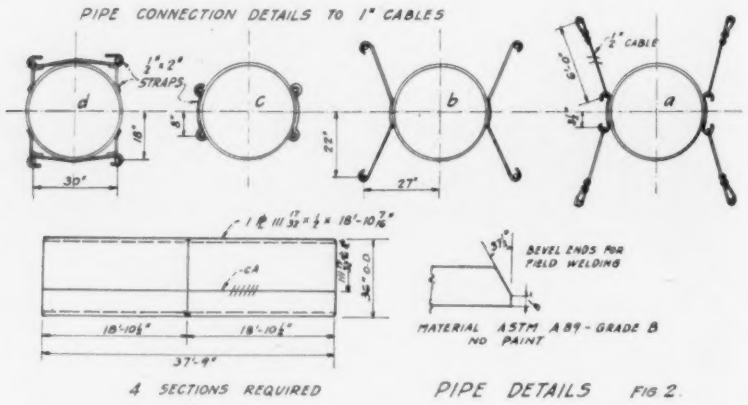
1. Flexibility of the cable, especially caused by temperature changes and wind, does not provide a uniform and rigid support for the pipe, and would permit excessive deflection of that pipe in a distance of 126′ from center to center of tower supports, making welded joints inadvisable.

2. The back stays were objectionable from point of view of pedestrian traffic.

3. Dresser coupling or riveted jointing would be necessary for the main pipe, and the installation and maintenance of the same would be a serious problem at the required height above the street surface, as well as in the distance above the existing operating elevated train structure.

4. The high maintenance cost was to be expected from the necessity of carefully watching the coupling joints, to avoid possible leakage of gas, as well as a continuous adjustment of the suspension rods, and back stays to maintain the structure at the necessary height. Over a period of 4 years, it is normally expected that cables will stretch and will require adjustment.

The details for hanging the pipe, while supported on wood saddles, would also require continuous maintenance, because of the shrinkage and wear of the wood support.



All of the above objections were eliminated by the revision in design (see Fig. 1). Basically the new design is a self restrained suspension bridge type without back stays. Steel towers are used, the welded 36″ gas pipe is used as a strut between towers, and the deflection of the pipe is reduced by cables, from which this pipe is suspended at a number of points. In addition to the main cables above the pipe, two supplementary cables are provided below the pipe to prevent lateral movement due to wind forces. At all times, the cables are in tension and the pipe is in compression. It is therefore perfectly safe to use welded joints in the pipe, and there is no danger of such joints opening up because of tensile strains. The surplus compression also prevents any tensile strains from vibration or shock.

As far as the cost is concerned, the elimination of the back stays and the dead men, the elimination of wood supports, and the use of welded connectors on the pipe from which cable suspenders attach the pipe to the main cables, all reduce the possibility of expensive upkeep. As a matter of fact, it

FIG. C.

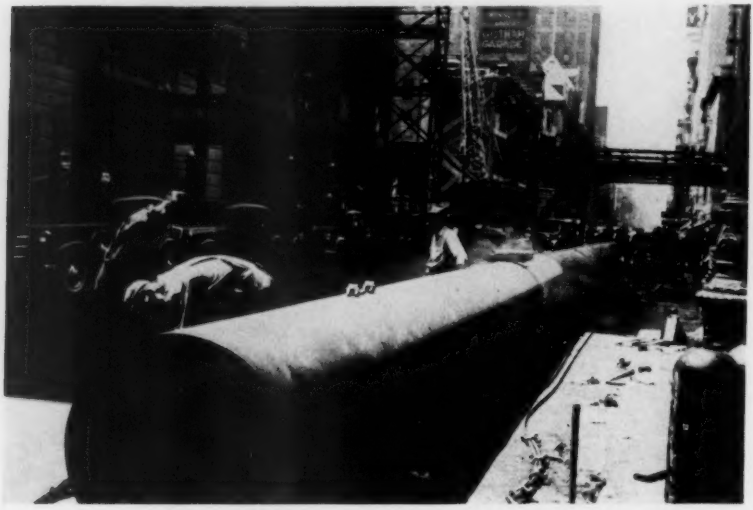
Erecting tower.

practically eliminated all upkeep costs in a period of 4 years, that this structure served the required purpose. In addition, the first cost is less than that of former types.

In designing this structure (see Appendix A for details of the design), the economy resulting from the use of welded connections was carefully considered and employed. With the exception of the steel towers, which were fabricated in a

local shop as a unit, and the cables, the entire structure is welded. The 36″ O.D. steel pipe with $\frac{1}{2}$″ wall was delivered in four 37′-9″ sections. Each section was made up of two plates 111-17/32 × $\frac{1}{2}$″ curved and butt fusion welded in the shop into a 36″ O.D. pipe. The ends were beveled on a $37\frac{1}{2}°$ slope with a $\frac{1}{8}$″ square edge on the inside of the pipe. The two units were then shop fusion welded into a single section of 37′-9″. Each section was tested before shipment

FIG. *D*.

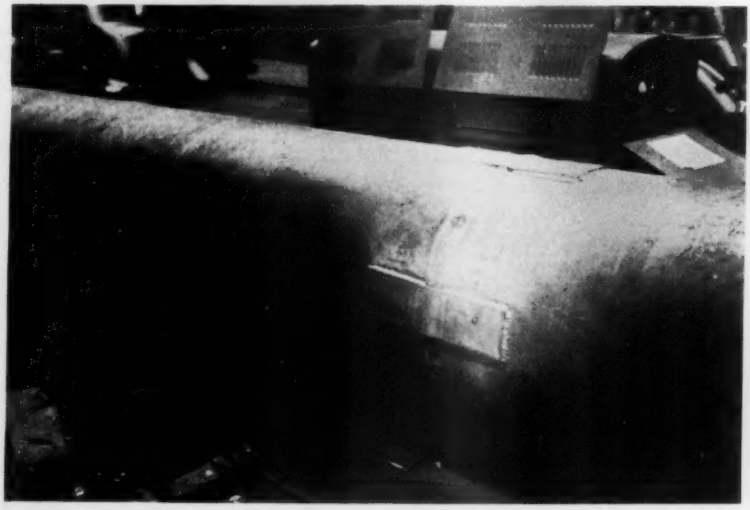


Welding pipe sections on ground.

with a hydraulic pressure test at 300 lbs. per square inch (see Fig. 2). Upon completion of the field welding, there resulted a single pipe 151 feet in length, weighing almost 16 tons including 1000 lbs. for the connectors and straps connected to the pipe. Welding rods were $\frac{1}{4}$″—No. 1 Special steel.

These four lengths were lined up on timber blocks on the street surface, and electric welded with the use of a Lincoln 300 ampere 40 volt, Shield Arc portable welder, with gasoline engine. The generator is rated 300 ampere N.E.M.A. and has a current range from 90 to 375 amperes. The engine is a 6 cylinder heavy duty Buda, with full load speed of 1400 r.p.m.

FIG. *E*.



Welding straps on pipe joint.

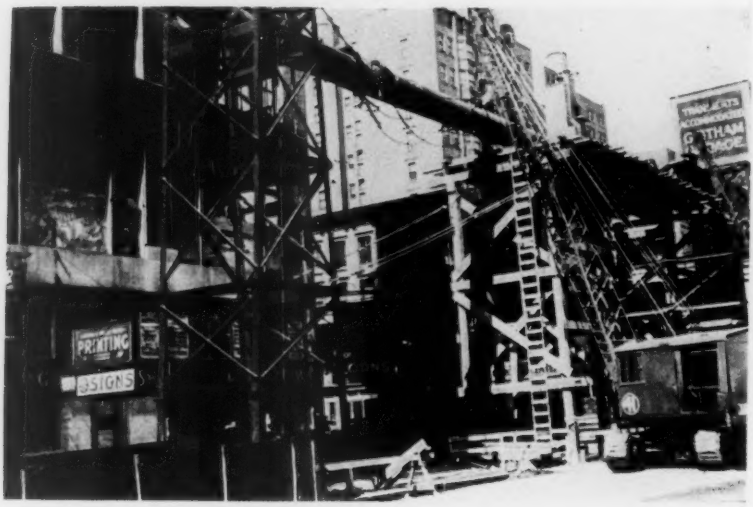
FIG. *F*.

Welding machine.

The three joints were made on three successive days, total labor consisting of one welder with part time assistance from a helper. Total labor cost for the three joints was less than $40.00. The rate of progress averaged $4\frac{1}{2}$ minutes per inch of weld.

In the final erected position, these butt welds would be sufficient, but there was a construction operation which had to be taken care of. To get this completed pipe into position

FIG. G.



Erecting pipe on towers—Note timber protection over "L" structure.

above the elevated structure, it was necessary to raise it by means of two cranes above the clearance level of the elevated structure trains, thread the pipe through one tower, and then pass it over the elevated structure, at which point the third crane picked up the overhanging end and threaded it through the second tower. During this work, without the cable intermediate supports, the theoretical deflection of the pipe would be 6″ due to dead weight alone. To prevent such a deflection straining one of the joints, four—$2'' \times \frac{1}{2}''$ steel straps 2′-0″ long were welded to the steel pipe across each of these joints. The straps were welded all around with a $\frac{3}{8}''$

fillet. For connecting the cables to the pipe, steel hooks and bands were made up in the blacksmith shop, and welded to the steel pipe. These rigid connections were designed to maintain a definite relation between the various cables at each location. On each end of the pipe, it was necessary to connect

FIG. *H*.

Erecting pipe-end view.

a channel and angle frame to provide a bearing for the tower against the gas pipe when the cables were tightened up. Because of the small clearance, these angles and channels were welded to the pipe after the pipe had been placed into the towers. The main cables are 1" mild plow steel, "cradled" to aid in preventing wind sway.

FIG. J.

Hanging cables.

FIG. K.

Completed supported pipe line.

The total labor cost for welding all of the connections and the joints in the pipe itself was $97.80, the hourly rate for a welder being $1.12½ per hour.

All the welding and tower erection were completed in one week, and the pipe was placed on to the towers in a period of 4 hours starting about 5:00 A.M. Sunday morning, when the pedestrian traffic was at a minimum in this district. The main cables were placed in position the same day, so as to release the strain on the pipe due to its own weight.

FIG. L.

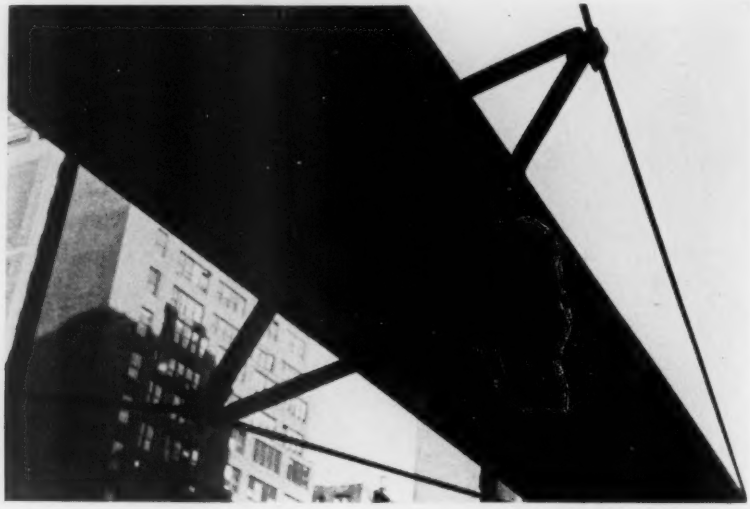
Detail of pipe brace connection at tower.

As a test for the strength of the welds and the assumption that the welded pipe was equal in strength to a single piece of pipe, the entire length of 150′ was raised as a unit over the street surface by two cranes one at each end, and the deflection was measured. In place of the theoretical deflection of a pipe of this dimension of 6⅔″, the actual deflection as determined in this test was somewhat less than 4″, showing that the welding of the joints had not decreased the strength of the unit, and that the straps across the joints had stiffened up the pipe structurally. Following this test, a careful examination

of all joints showed no failures in any of the weld material and the pipe was then placed in position.

Total labor of placing the pipe in position and in attaching the main cables was $283.55 (about $\frac{1}{3}$ of this is double time payment for Sunday work). The following two days all cables were adjusted and the pipe was given a coating of a rust resisting compound and paint. The total labor cost of welding and erection of the towers including the cost of

FIG. *M*.



Cable connector at quarter point.

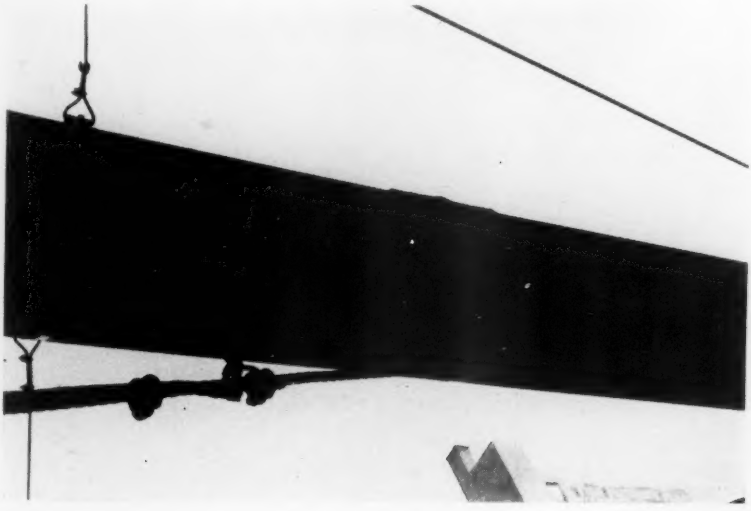
timbermen and laborers to provide protection for pedestrian traffic, as well as the elevated structure during the erection, was $680. Labor of all welding was $135.40, of painting $36.60. To this cost must be added the value of three cranes for one day, the labor involved being included in the totals above, as well as insurances and overhead. The cranes and the welding machine were owned by the Company, however in compiling the costs, standard rentals are charged against this work.

The entire cost of materials for pipe and towers and miscellaneous items, of labor, and insurances, of equipment

FIG. *N*.

Joint and plates after 2 years service.

FIG. *P*.



Hanger clip and joint.

and overhead charges for the total construction was $8900, or a per foot cost of $59.00 for both the pipe and support. Roughly, the cost of the pipe and the cost of the supports were equal, showing a total cost of $29.50 per foot of pipe in place on prepared tower supports.

The total cost is made up as follows:

Labor	$1677.45	
Insurances and Taxes	362.84	
Materials:		
Towers	1371.90	
Cables, etc.	330.04	
Concrete for Footings	252.62	
I.R.T. Flagging	81.24	
Rope and Lumber	235.74	
36" Pipe	1707.41	
Couplings for Legs	249.76	
Weld Wire, etc.	175.35	
Gas and Air	144.83	
Paint	164.79	
		$4713.68
Equipment and Haulage Charges:		
Haul Cranes	$ 135.00	
Haul Pipe and Towers	181.50	
Truck Cranes (2½ d.)	60.00	
Large Cranes (8 d.)	236.00	
Weld. Machines (1 mo.)	128.00	
Fuel for Welding and Cranes	33.50	876.00
Total Direct Costs		$7629.97
Overhead Charges, etc.—$\frac{1}{6}$		1271.66
		$8901.63

COMPARISON WITH PREVIOUS DESIGNS.

In addition to the direct savings, there are the additional savings in costs in the reduction of upkeep of the welded pipe as against a riveted pipe, such as the necessity for additional painting and recaulking the joints due to disturbances from temperature and wind movements, the reduction of possible accidents because of the elimination of cable back guys, and the possible loss of gas service due to necessary shut-offs if the leakage in the joints become serious. It might be well to point out, that in previous contracts a great number of acci-

dents have occurred at the location of the back guys on this type of structure, where pedestrians have accidentally tripped against the lower portion of the back guys, or hit against an upper portion where headroom is not sufficient. The elimination of the back guys of course does away with these dangers.

From a point of view of efficiency, the welded pipe and self sustaining suspension support is far superior to the usual type of riveted pipe with back guys. The use of the pipe as a compression member not only increases the efficiency of the weld and eliminates the possibility of tension at the joints with resulting leakage, but is a considerable saving in cost. As a matter of fact, the revised type of design has become more common, and very shortly should be the standard method of supporting overhead gas by-pass in City subway construction work. This type of design can very well be applied to crossings of pipes not only for gases, but also for liquids where such crossings have to be carried above streets, railroads, highways and streams. The advantages of welding in this type of structure can be applied to a great number of locations, although the development was one item in the construction of the City subway rapid transit system.

ACKNOWLEDGMENTS.

The first overhead gas by-pass of this type was executed in connection with the construction of the Union Ave. Subway in Brooklyn, in 1931, by Gustave Jacobi for the Rosoff Subway Company. In this case, wood towers were used and the cables were designed to carry the full pipe weight. The design described in this article was prepared for the Rosoff Brader Construction Co. by the writer, with the coöperation of Mr. Jacobi, who was a member of the engineering staff. A similar design was later used for a pipe crossing 6th Avenue at 35th Street by the Park Contracting Co. References to previous articles on the subject of overhead gas by-pass lines are:

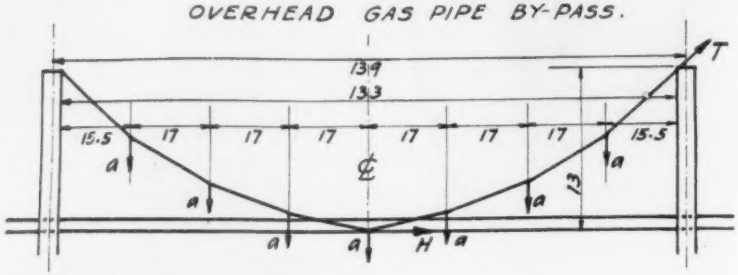
L. M. CHARM: "New York's Third Subway," *E. N. R.*, **97**, 568–72, No. 15 (1926).

M. I. KOHN: "Subsurface Structures in Subway Construction," *Eng. and Contr.*, August 1927, pp. 369–74.

WM. O'LEARY: "Hazard of Live Gas Mains in Subway Construction," *E. N. R.*, Mar. 12, 1936, pp. 373–8.

COMPUTATIONS FOR DESIGN APPENDIX A.

OVERHEAD GAS PIPE BY-PASS.



DEFLECTIONS OF UNIT LOAD:

PIPE AS A SIMPLE BEAM – 36" O.D., $\frac{1}{2}$" THICK

$$I = 0.049087\,(d^4 - d_1^4) = 8787 \text{ IN.}^4$$

$$\delta_p = \frac{5}{384} \times \frac{139^4 \times 12^3}{29\,000\,000 \times 8787} = 0.0330 \text{ INCHES (PER \#/FT.)}$$

CABLE WITH UNIT LOAD PER FOOT: ASSUME 1" MILD PLOW STEEL 6×19 HEMP CENTER CABLE, $E = 13,000,000$, $A = 0.3972$ SQ.IN., WEIGHT 1.60 \#/FT

$$\text{ELASTIC STRETCH} = \frac{Pl}{AE} = \frac{176 \times 136.39 \times 12}{0.3972 \times 13\,000\,000} = 0.0556 \text{ INS.}$$

l = LENGTH OF CABLE $= S + \frac{8d^2}{3S} = 133 + \frac{8(13)^2}{3 \times 133} = 136.39$

P = AVERAGE STRESS IN CABLE FOR UNIT LOAD ON CABLE, IS FOUND AS FOLLOWS:

$a = 17$, $H = \left(8.5 \times 66.5 + 17[49.5 + 32.5 + 15.5]\right) \times \frac{1}{13} = 171$

$$V = 3\tfrac{1}{2} \times 17 = 59.5$$

$$T = \sqrt{171^2 + 59.5^2} = 181$$

$$P = \frac{171 + 181}{2} = 176$$

$\Delta\delta_c$ = INCREASE IN SAG DUE TO UNIT LOAD PER FT.

$$= \frac{15\,\Delta l}{16(5b - 24b^3)} = \frac{15\,(.0556)}{16(.489 - .0244)} = 0.1122 \text{ IN.}$$

Δl = ELASTIC STRETCH OF CABLE

$$b = \frac{d}{S} = \frac{\text{SAG}}{\text{LENGTH}} = \frac{13}{133} \text{ OR } 0.0978$$

COMPUTATIONS FOR DESIGN APPENDIX A (CONT)

PIPE 36" O.D. x $\frac{1}{2}$" THICK 205 #/FT. VERTICAL LOAD.

WIND @ 30 #/□ FT. x 0.6 RATIO FOR CIRCULAR SHAPE

ON 3 FT EXPOSURE = 54 #/FT. HORIZONTAL.

(a) RESULTANT① $= \sqrt{205^2+54^2} = 212$ #/FT.

OR PIPE 205 #, 1/2" ICE @ 50 #/CU.FT. = 20#/FT.

PLUS 8# WIND = 24# PER FT. HORIZONTAL

(b) RESULTANT② $= \sqrt{225^2+24^2} = 237$ #/FT.

DEFLECTION PER UNIT LOAD: PIPE AS BEAM 0.0330"

" " " " 2 CABLES 0.0561"

0.0891"

PIPE AS A BEAM TAKES $\frac{0561}{0891}$ OR 63% OF 205# = 149#/FT.

TWO CABLES TAKE $\frac{0330}{0891}$ OR 37% OF 205# = 88#/FT.

STRESSES PER CABLE: $H = \frac{171 \times 88\#}{2 \text{ CABLES}} = 7500$ #

MAX. $T = 181 \times \frac{88\#}{2} = 7960$ #

1" CABLES ASSUMED ARE O.K.

STRESSES IN PIPE: LOAD OF 149#/FT. & 2x7500# COMPRESSION

PIPE AREA 60.3 □", $\frac{15\,000\#}{60.3} = 250$ #/□" COMPRESSION

BENDING STRESS: $\frac{149 \times 139^2 \times 18 \times 12}{8 \times 8787} = 8850$ #/□"

APPROX. COMBINED STRESSES { 9100 #/□" MAX, 8600 MIN.

ACTUAL DEFLECTIONS 0.0330 x 149 = 4.9" (PIPE)

$\frac{0.1122}{2} \times 88 = 4.9$" (CABLES)

(NOTE: CABLES CRADLED AND LOWER CABLES FOR WIND LOAD)
TOWERS AND FOOTINGS DESIGNED FOR WIND LOAD.
UPPER CABLES SET ON TRUE PARABOLA UNDER
DEAD LOAD ONLY

Earthquakes Influence Tower Design.—(*Engineering News Record*, Vol. 125, No. 25.) The Hoover Library on War, Revolution and Peace at Stanford University, California, is only two miles from the active San Andreas fault, and as its function is to provide a permanent repository for valuable records precautions were taken to safeguard the structure against earthquake damage. For monumental effect the main element of the structure is formed by a tower $52\frac{1}{2}$ feet square and 279 feet high; earthquake-resistant design of this tower was the principal problem. Though carried by steel framework, the tower is enclosed with reinforced-concrete walls designed to resist earthquake stresses while the steel frame is braced to resist wind loads only. To carry the horizontal forces from the tower to the outer walls of the two-story structure at the base and thereby distribute them over the 122 ft. square of the base, the roof of the base structure was made six inches thick instead of the four inches that would have served other purposes. The maximum force of 0.1 g. was the basis of design. This force must be resisted by the concrete outer walls, as stress analysis indicated that because of their stiffness these walls would take 98 per cent. of the horizontal earthquake force even though the steel were designed strong enough for earthquake stresses. Were the walls made light and dependence placed on the steel frame, a severe shock probably would damage the walls badly, while with the actual design even a shock of 0.1 g. intensity is not expected to damage the walls seriously, and what might be heavy repair costs will be avoided. The foundation is sand, clay and gravel which load tests show to be almost perfectly elastic within the range of loading. The maximum combined earthquake and direct loading on the foundation beneath the $5\frac{1}{2}$ feet concrete mat which underlies the tower is about six tons per square foot. This loading was decided upon after static and dynamic load tests were made on the foundation.

R. H. O.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

LOUISE A. BOYD ARCTIC EXPEDITION.

Successful long-distance radio transmission is dependent upon many natural phenomena, some of which are not well understood. Data on them, to be of real value, must be obtained at many points on the earth's surface, not merely at places where regular laboratories happen to be located. For instance, what takes place in the ionosphere (the electrically conducting layers of rarefied air at heights of from 50 to 300 miles above the earth's surface) anywhere along the path of radio signals must be known if predictions of transmission conditions, such as are made by the Bureau each month, are to have maximum reliability. It was for this reason that the Bureau designed special portable ionosphere equipment. This was used last year to make observations in Texas and in Brazil during solar eclipses (*Technical News Bulletin 289;* May, 1941). Data from points in the arctic region are lacking, and it is to fill this gap that a unique scientific expedition under the leadership of Miss Louise A. Boyd was undertaken at the Government's request, Miss Boyd having been appointed a consulting expert of the Bureau. The expedition sailed from Washington on June 11 for far northern waters. Both Miss Boyd and Captain Bob Bartlett, who commands the schooner "Effie M. Morrissey," are arctic explorers of wide experience. The expedition will observe ionosphere characteristics as determined by special radio measurements, geomagnetism, auroral manifestations, and will also measure the intensities of ultraviolet light and cosmic rays.

The United States Coast Guard and the Department of Terrestrial Magnetism of the Carnegie Institution coöperated in the arrangements for the expedition and will benefit from its findings.

* Communicated by the Director.

THIRTY-FIRST NATIONAL CONFERENCE ON WEIGHTS AND MEASURES.

The attendance at the Thirty-first National Conference on Weights and Measures, held at the Mayflower Hotel in Washington on June 3 to 6, was particularly gratifying, considering present unsettled conditions. Two hundred and fifty-one members and guests registered from 28 states and the District of Columbia.

In his opening address as President of the Conference, Dr. Lyman J. Briggs reviewed the Bureau's weights and measures work during the past year. He announced the completion of the vehicle-scale testing program, but stated the Bureau might be able to conduct a limited number of resurveys in States that have not yet secured adequate testing equipment. A new method has been adopted for identifying "Class A" precision weights certified by the Bureau, which does away with the necessity of stamping the weights and thereby possibly injuring the gold plating. There is a definite prospect that Bureau representatives can again attend some State and local weights and measures conferences, as certain funds made available through completion of the vehicle-scale tests will be available for travel. Dr. Briggs requested all officials to coöperate with the Bureau by furnishing timely items for inclusion in the Weights and Measures News Letter, eight numbers of which have been issued.

The place of the weights and measures officer in the defense program was the subject of an address by Dickson Reck, economist, Consumer Division, National Defense Advisory Committee. Mr. Reck stated that important economies can be effected through the coöperation of consumers with weights and measures inspectors. The household purchaser comes in contact with the economic system at the retail store and it is in these transactions that waste must be eliminated. He emphasized the importance of uniform laws, adequate supervision of weighing and measuring apparatus in use, and the need for a more alert attitude on the part of the public. He invited weights and measures officials to call upon the Consumer Division for aid and to give him the benefit of their experience.

The formal papers presented covered the following sub-

jects: Directing the personnel of a weights and measures department, James O'Keefe; Activities of the National Scale Men's Association, Harry Mayer; Testing of apparatus used for measuring liquefied petroleum gases, Charles M. Fuller; Air elimination for large-capacity meters, C. P. Griffith; Vehicle-tank piping design, C. H. Engelhard; Development of single-service containers, C. E. Hawkins; The manufacture of precision glassware, J. J. Moran; Report on testing of vehicle scales by the National Bureau of Standards, Ralph W. Smith; Weighbeams, J. J. Harrison; Local "master" vehicle scales, Louis E. Witt; Platform overhang of vehicle scales, C. L. Richard. All scheduled papers were memeographed in advance of the Conference, so that every delegate was provided with copies. This added greatly to the value of the discussion which followed the presentation of each paper.

The Conference went on record as favoring certain changes in the specifications, tolerances, and regulations for weighing and measuring devices, including the adoption of a new code for single-service containers (except milk bottles). Changes were also recommended in regulations governing the sale of 16 classes of commodities, such as meats, dried fish, flour, tea, cheese, paper of various kinds, matches, and twine. Approval was recorded of legislation now pending in Congress concerning the use of net weights in interstate and foreign commerce transactions in cotton.

Probably the most important action of the Conference was the approval of a proposed Federal bill for food package standardization (except malt liquors, wines, and spirits). The bill makes mandatory the packing of retail packages of food in certain prescribed units. Either a weight or volume basis is to be used depending upon the nature of the commodity, and it may be remarked that the proposed legislation is in complete agreement with established weights and measures principles. The following committee to sponsor the bill was appointed: Alex Pisciotta, Director, New York City Bureau of Weights and Measures; George M. Roberts, Director, Bureau of Weights, Measures, and Markets of the District of Columbia; and J. H. Meek, Director, State Division of Markets, Richmond, Va.

The officers of the Conference elected for the coming year

are: President, Lyman J. Briggs, National Bureau of Standards; Vice Presidents, J. F. Blickley, Pennsylvania, G. K. Heath, Maine, M. A. Hubbard, Virginia, J. G. Rogers, New Jersey, W. P. Reed, Georgia, L. E. Witt, Wisconsin; Secretary, Ralph W. Smith, National Bureau of Standards; Treasurer, George F. Austin, Detroit, Michigan.

CATHODE FILMS IN ELECTRODEPOSITION.

It is well known that during electrodeposition of a metal, the concentration of that metal decreases in the solution adjacent to the cathode. Under the usual operating conditions, the principal changes occur within a short distance from the cathode in a thin layer called the cathode film. Hence, deposition actually takes place from a solution having a composition which differs from the nominal composition of the bath. Beyond the cathode film is a convection region of indefinite extent (perhaps 0.1 inch thick) in which the depleted solution is forced upward by the more dense, concentrated solution in the body of the bath.

Cathode films have been studied by two methods. In the freezing method (*Technical News Bulletin 279;* July, 1940) the film is isolated by pouring a very cold liquid into a hollow cylinder, on the outside wall of which electrodeposition is taking place. The drainage method consists in quickly removing a plane cathode from the plating bath, allowing it to drain for a brief period, and then collecting the film that adheres to it. In a paper before the annual convention of the American Electroplaters' Society on June 10, Abner Brenner stated that at 25° C. the thickness of the film was found to be about 0.010 inch in unstirred baths. The film is completely formed in about 2 minutes after the start of electrolysis, but it dissipates somewhat more slowly after the circuit is broken. The changes in concentration of the solution at the cathode produced by electrolysis under various conditions in typical plating baths have been determined. Most of these results can be explained qualitatively by simple theoretical considerations.

GLASS ELECTRODE AND CHEMICAL DURABILITY.

In a previous publication, it has been shown that the departures from a linear relation between the voltage of the glass electrode and pH of the solutions are accompanied by changes in the chemical durability of the glass. Additional studies have been made by Edgar H. Hamilton and Donald Hubbard to ascertain to what extent the chemical durability of the electrode glass is associated with voltage departures, voltage irreversibility, and potential drift of the electrode in alkaline solutions. The results will be found in RP1400 in the July *Journal of Research*. The attack-voltage departure relation appears to be a straight line, while the voltage irreversibility and potential drifts are qualitatively consistent with a durability interpretation.

It is known that glass surfaces after suitable treatment have the capacity to absorb certain dyes such as Victoria Blue B. By applying this property, it has been shown that the inner and outer surfaces of electrode bulbs are very different and hence asymmetry potential may be correlated with the relative chemical durabilities of these two surfaces.

ENZYMATIC HYDROLYSIS OF DISACCHARIDES.

Since the glycosides are combinations of sugars and alcohols, or phenols, the disaccharide sugars may be considered as glycosides for which the aglucon is a sugar rather than an alcohol. Weidenhagen has classified the glycoside hydrolyzing enzymes according to the sugar which is connected to the alcohol or phenol (the glycosidic sugar) and according to the alpha or beta configuration of the carbon atom of the sugar which is involved in the linkage to the alkyl or phenyl radical. Because of the relation of the glycosides to the disaccharides, it has been believed that an enzyme which hydrolyzes a glycoside should also hydrolyze disaccharides with the same glycosidic sugar and with the same alpha or beta configuration. Thus, the enzyme β-glucosidase should hydrolyze all β-glucosides and those disaccharides (cellubiose and gentibiose) which may be considered as β-glucosides. In order to test this aspect of the much criticized Weidenhagen theory, William Ward

Pigman has made measurements of the rate of enzyme hydrolysis of several disaccharides under standard conditions. As reported in RP1398, in the *Journal of Research* for June, it was found that in agreement with Weidenhagen's ideas, gentiobiose, 4-glucosidomannose, and lactositol are all hydrolyzed by the enzymes from almond seeds (almond emulsin). The results previously obtained for other disaccharides and derivatives, when placed on a comparable basis, show very interesting and pronounced effects of small changes in the configuration and structure of the aglucon group on the rate of enzymatic hydrolysis. These effects are found to be in agreement with the accepted concept that the enzyme and glycoside or disaccharide form an intermediate absorption complex, particularly when this concept is modified according to the suggestion of Euler by assuming that the enzyme is attached to both of the component sugars of the disaccharide molecule.

The preparation by D. H. Brauns of a series of substituted phenyl β-glucosides, differing only in nature of the atom in the para position of the ring, made it possible to study the enzymatic hydrolysis of the *p*-halogen salicins (*p*-chloro-, bromo-, and iodo-*o*-hydroxymethylphenyl β-glucosides). These compounds were found to be more slowly hydrolyzed than the unsubstituted salicin and the magnitude of the reaction constants for their enzymatic hydrolysis under fixed conditions decreases in the following order: Salicin > iodosalicin > bromosalicin > chlorosalicin.

THE FRANKLIN INSTITUTE.

LIBRARY NOTES.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print 9 × 14 inches is thirty-five cents.

The library and reading room are open daily from nine o'clock A.M. until five o'clock P.M. Saturdays until 12 o'clock noon.

RECENT ADDITIONS.

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NAVAL ARCHITECTURE.

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KAHAN, THÉODORE. Radioactivité et Transmutation des Atomes. 1940.

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WOOD, ALEXANDER. Acoustics. 1941.

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CROWTHER, J. G. Social Relations of Science. 1941.

SUGAR.

GILMORE, A. B. The Puerto Rico Sugar Manual. 1940–41. 1941.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, June 11, 1941.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, JUNE 11, 1941.

MR. COLEMAN SELLERS, 3RD, *in the Chair.*

The following reports were presented for final action:

No. 2994: Work of Jesse Wakefield Beams.

This report recommended the award of a Howard N. Potts Medal to Jesse Wakefield Beams, of Charlottesville, Virginia, "In recognition of his contributions to the problem of high speed rotation and of his successful development of a wide variety of ultracentrifuges."

No. 3083: Thread Grinding Machinery and Process.

This report recommended the award of an Edward Longstreth Medal, jointly, to Ralph E. Flanders and Ernest V. Flanders, of Springfield, Vermont, "In consideration of the development of a thread grinding machine, including a method for truing the grinding-wheel, its mounting and control, insuring accuracy and variability of the resulting screw threads."

JOHN FRAZER,
Secretary to Committee.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

A SINGLE COMPONENT FOR THE PRIMARY COSMIC RADIATION.*

BY

W. F. G. SWANN.

With reference to the *Letter to the Editor* entitled "The Nature of the Primary Cosmic Radiation and the Origin of the Mesotron," by M. Schein, W. P. Jesse and E. O. Wollan,[1] I wish to point out that identical conclusions have been cited by the present writer from other considerations. These conclusions, which are covered in three published communications,[2] are as follows:

(1) There is *only one type of primary radiation*, a charged particle radiation—probably protons—comprising particles of heavy mass.

(2) By processes at present unknown, the *primary radiation gives birth, probably indirectly, in the upper atmosphere, to mesotrons.*

(3) Those mesotrons which are born approximately at rest will have such short lives that they will disintegrate before they have traveled more than 300 meters. *They will, in fact, disintegrate in the stratosphere, and in so disintegrating, will give rise to electrons which, on account of the disintegration occurring from mesotrons at rest, will emerge on the average equally in all directions.*

(4) The mesotrons formed with higher energy will disintegrate at lower altitudes, because of their longer lives, and *because they disintegrate at high energy, will give rise to electrons which possess on the average a forward component at these lower altitudes.*

* Reprinted from *The Physical Review*, **59**, 770 (1941)

[1] M. Schein, W. P. Jesse, and E. O. Wollan, *Phys. Rev.*, **59**, 615 (1941).

[2] W. F. G. Swann, *Phys. Rev.*, **56**, 209 (1939); *Rev. Mod. Phys.*, **11**, 242 (1939). (See, in particular, pp. 251–254.) *Phys. Rev.*, **58**, 200 (1940).

(5) The assumptions (1) and (2) lead, through the logical consequences (3) and (4), to an explanation of the following facts: (*a*) As shown by the Bartol Foundation's observations in the two National Geographic—U. S. Army Air Corps Stratosphere Flights [3, 4] and in the Jean Piccard Flight,[5] *the curve of intensity versus zenith angle flattens out with increasing altitude* to a condition in which, at a depth of 0.5 meter in the water equivalent atmosphere, there is only a 20 percent change from vertical intensity to horizontal intensity. (*b*) As shown by our stratophere observations in *Explorer II* [4] and independently by the observations of T. H. Johnson and J. G. Barry,[6] *there is no appreciable azimuthal asymmetry at high altitudes*. It was, of course, to provide for the experimental facts cited under (*a*) and (*b*), that the hypotheses (1) and (2), with the consequences (3) and (4), were formulated.

(6) Any incoming electrons of primary origin and of one sign would necessitate azimuthal asymmetry and primary electrons of one sign or of both signs would cause strong dependence of intensity upon zenith angle. The absence of such effects prohibits assumption of the existence of any primary electrons and *necessitates that all the cosmic-ray electrons be born from the mesotrons in accordance with* (2).[7] *In other words, there can be no primary electrons.*

That the primary cosmic rays are *in part protons* has been suggested by A. H. Compton and H. Bethe,[8] and also by T. H. Johnson.[9] A single primary radiation of protonic nature giving rise to mesotrons and through them to the cosmic-ray electrons was suggested by the present writer [10] prior to his

[3] W. F. G. Swann and G. L. Locher, Nat. Geog. Soc. Contr. Tech. Pap., Stratosphere Series No. 1, pp. 7–14 (1935).

[4] W. F. G. Swann, G. L. Locher, and W. E. Danforth, Nat. Geog. Soc. Contr. Tech. Pap., Stratosphere Series No. 2, pp. 16–25 (1936).

[5] W. F. G. Swann, J. FRANK. INST., **222**, 1 (1936). (See, in particular, pp. 45–58.)

[6] W. F. G. Swann, *Phys. Rev.*, **56**, 209 (1939).

[7] And to a negligible extent by shower production, which phenomenon, however, becomes relatively more important in the lower atmosphere.

[8] A. H. Compton and H. Bethe, *Nature*, **134**, 734 (1934); also A. H. Compton, *Rev. Sci. Inst.*, **7**, 71 (1936).

[9] T. H. Johnson, *Phys. Rev.*, **45**, 569 (1934).

[10] W. F. G. Swann, J. FRANK. INST., **226**, 757 (1938). (See, in particular, pp. 780 and 792.)

more detailed development of these ideas in papers cited.[2] T. H. Johnson [11] also suggested protons as the parents of the mesotrons but invoked a primary electronic radiation in addition.

ON TIME LAGS IN COINCIDENT DISCHARGES OF GEIGER-MÜLLER COUNTERS.*

BY

M. E. ROSE AND W. E. RAMSEY.

In specific ionization measurements with Geiger-Müller counters it has been observed that the efficiency of oxygen counters is abnormally low, indicating about 30 per cent. of the expected ionization by cosmic-ray particles.[1] As an explanation of this anomalous result it has been suggested that, as a result of electron capture, time lags [2, 3] are introduced between the passage of the ray through the counter and the initiation of the discharge.

To test this hypothesis and to study these time lags we have used a vertical arrangement of three counters in coincidence with the two outer counters sufficiently small so as to define the path of the cosmic-ray particles which were used as the primary radiation. By moving these exploring counters relative to the central counter (see Fig. 1) the (local) efficiency of the latter could be measured, as a function of resolving time of the amplifier, for various distances between the point of origin of the electrons and the counter wire. The resolving time, during which the central counter must be discharged to produce a count, was measured with a pulse generator which supplied known pulses separated by known time intervals.[2] The amplifier circuit, which was designed for great sensitivity, was subjected to the most stringent tests to insure that all

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[11] T. H. Johnson, *Rev. Mod. Phys.*, 11, 208 (1939).

* Reprinted from *The Physical Review*, 59, 616 (1941).

[1] W. E. Danforth and W. E. Ramsey, *Phys. Rev.*, 49, 854 (1936) and unpublished results.

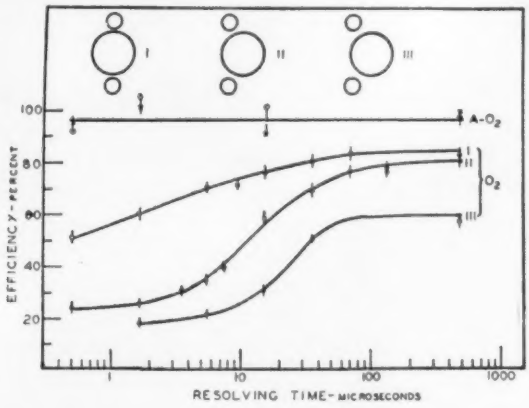
[2] C. G. Montgomery, W. E. Ramsey, D. B. Cowie and D. D. Montgomery, *Phys. Rev.*, 56, 635 (1939).

[3] J. V. Dunworth, *Nature*, 144, 152 (1939).

spurious effects were eliminated. The runs were repeated in random order and the results were found to be fully reproducible.

The measurements were made for two extreme cases; namely, for oxygen which has a comparatively large capture cross section and for an A − O_2 mixture (6 per cent. O_2) which is known to be very efficient and for which very little capture effect may be expected. The efficiency of the O_2 counter (Fig. 1) is seen to be rather low and to exhibit a very pro-

FIG. 1.



Counter efficiency as a function of resolving time (logarithmic scale) for oxygen and A−O_2 (0.94 A, 0.06 O_2). The curves *i*, *ii* and *iii* were obtained with the positions of the exploring counters as shown in the upper portion of the figure. Standard statistical errors are indicated. For the A−O_2 counter, the crosses refer to position *i* and the circles to position *ii*. The exploring counters were 1 cm. in diameter, 20 cm. long; the central counter was 2.7 cm. in diameter, 29 cm. long. In each case the gas pressure was 9 cm. Hg.

nounced time effect which is readily interpretable in terms of capture. At the pressure used (9 cm. Hg) the total ionization of cosmic rays in the counter should be rather small [1] (2–5 ion pairs) and there is an appreciable chance that *all* electrons formed will be captured before they reach the wire. The time lags, between the discharges in the central and exploring counters, will be statistically distributed about a most probable value ($\sim 10^{-5}$ sec.). The resonance-like form of the curves in Fig. 1 may then be understood. At small resolving

times very few ions reach the vicinity of the wire in time for a coincident discharge whereas at long times all of them reach the wire in time so that the efficiency is then mainly determined by the probability for cosmic-ray ionization. The distribution in time lags is obviously given by differentiation of the curves. The effect of changing the path length for cosmic-ray ionization and for electron capture is shown by the three curves marked *i*, *ii* and *iii* and the results are clearly in accord with expectations.

Further confirmation of the capture hypothesis is obtained from more quantitative considerations. The probability q that an electron will be captured before reaching the wire is given in terms of the efficiencies at low and high resolving times (ϵ_0 and ϵ_∞, respectively) by

$$q = 1 - \log (1/1 - \epsilon_0)/\log (1/1 - \epsilon_\infty) \qquad (1)$$

and the probability of capture per collision is

$$p = 1 - (1 - q)^{1/N} \approx \frac{1}{N} \log \frac{1}{1 - q}, \qquad (2)$$

where N = total number of collisions. From curve *ii* one finds $q = 0.85$ and $p \approx 10^{-4}$. From the mean time lag (4×10^{-5} sec. from *ii*) and the mean distance traversed before capture (calculated from 2) the ionic mobility is found to be 2 cm.^{2}/sec./volt at atmospheric pressure. These results are in as good agreement with independent capture and mobility measurements as could be expected.[4]

In contrast to the results for O_2 the $A - O_2$ mixture shows an efficiency (97 per cent.) which is independent of resolving time and relative position of the counters.

In the interest of higher efficiency it may, therefore, be suggested that the use of gases which capture electrons easily should be avoided. Otherwise long resolving times are required and care should be exercised in changing circuit constants.

[4] L. B. Loeb, "Fundamental Processes of Electrical Discharge in Gases" (John Wiley and Sons, 1939).

OPERATION OF PROPORTIONAL COUNTERS.*

BY

S. A. KORFF.

Proportional counters have certain useful applications and have been used by various observers.[1] Such counters are distinguished from ordinary Geiger counters in that they are operated at voltages below the threshold, this potential being defined, following Montgomery and Montgomery,[2] as the lowest voltage at which all the pulses produced by the counter are of the same size.

A. PROPORTIONALITY

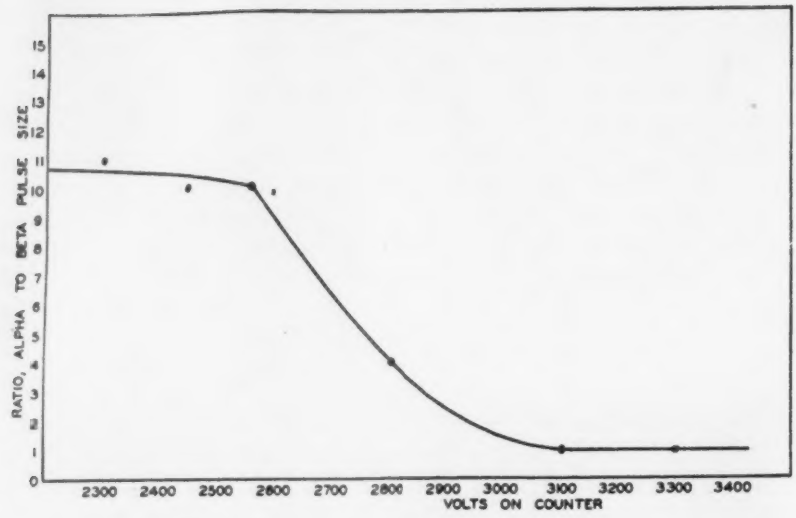
It was desired to investigate whether the sizes of the discharges were proportional, at all voltages, to the amount of ionization taking place in the counter. For this purpose, two ionizing events of different but fixed sizes were produced in the counter by projecting a collimated beam of alpha- and slow beta-particles through a thin window, thereby securing a definite path length of the particles through the counter. The alpha-particles ended their ranges in the cylinder, producing about 16,000 ion-pairs per particle. The beta-particles similarly produced, according to the range tables, about 1500 ion-pairs as they in turn ended their ranges in the cylinder. The ratio of the largest pulses produced by the alpha- to that of the beta-particles is presented in Fig. 1, as a function of voltage. It will be observed that this ratio remains constant as the voltage is increased until a potential of 2550 volts is reached, after which the ratio falls to unity at 3100 volts. This latter voltage is therefore by definition the threshold of the counter. In the voltage region immediately below the threshold, only limited proportionality is obtained. For proper proportional operation it is necessary to operate the counter at voltages considerably below the threshold.

* Condensed from a paper published in full in *The Review of Scientific Instruments*, **12**, 94 (1941).

[1] G. Brubaker and E. Pollard, *Rev. Sci. Inst.*, **8**, 255 (1937).

[2] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **57**, 1030 (1940). W. E. Ramsey, *Phys. Rev.*, **57**, 1022 (1940). Further bibliography will be found in the above two papers.

FIG. 1.



Proportionality of a proportional counter. Two ionizing events of different sizes are produced in the counter and the ratio observed. Below 2550 volts, proportionality is obtained; between 2550 and 3100 volts, limited proportionality is found. Above the threshold, 3100 volts, all pulses are the same size.

B. MEASUREMENT OF AMOUNT OF IONIZATION IN THE INITIAL EVENT

In order to interpret quantitatively proportional counter data, it is necessary to have a calibration determining the amount of ionization which takes place in the initial act. Such calibration can be made by projecting alpha- or beta-particles of known specific ionization into the counter through a thin window. In the case of alpha-particles projected through a window, a good calibration may be obtained by setting the counter voltage at the threshold and then measuring the distance D in air through which the alpha-source may be withdrawn from the window and still produce the minimum avalanche necessary to record as a count. It is obvious that

$$R = W + D + I, \tag{1}$$

where R is the range of the alpha-particle in air, W is the air equivalent thickness of the window, D is the distance in air of

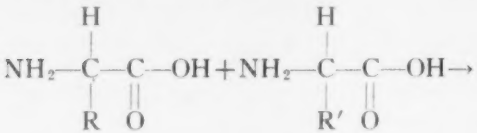
the source from the window, and I is the amount of ionization in the initial act (in units of alpha-particle range in air) which must be produced in the counter to produce a recorded count. It is assumed that, with any particular amplifier, an ionizing event must produce more than a certain minimum pulse size P on the counter wire in order to record as a count. The alpha-particle range R being known, measurement of this distance D determines the window thickness, since at the threshold the alpha-particle will produce a count if it produces but a single ion within the active volume of the cylinder (i.e., I is practically zero). As the potential on the counter is reduced, the gas amplification V is reduced, and the pulse arriving on the wire is smaller. Hence the alpha-source must be brought nearer the window in order to produce a count, the larger I compensating for the smaller V. Since its position D is measurable, this provides a convenient way of determining the amount of ionization I which must be expended in the counter in order to produce a count.

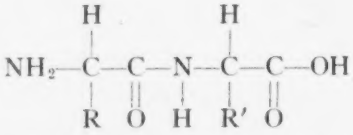
A beta-particle ending its range down the length of the counter cylinder will produce an amount of ionization large compared to that of an ordinary cosmic-ray particle crossing the counter. The maximum amount of ionization produced may be computed from the familiar electron range tables, and the obvious modification of Eq. (1) will then enable beta-particles also to be used in calibration.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Seminar on the Irradiation of Proteins.—On March the twentieth, DR. DWIGHT C. CARPENTER, Research Chief of the New York State Agricultural Experiment Station at Geneva, spoke on the monochromatic irradiation of proteins and related substances before the seminar group of the Biochemical Research Foundation and a number of guests.

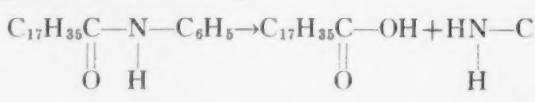
In 1903 Emil Fischer showed that proteins are built up of alpha amino acids through condensation of the amino group of one acid with the carboxyl group of the next to form the CONH or peptide linkage.





The bond energies which hold together the various atoms in peptides and amino acids have recently been calculated by Pauling and Niemann (*Journal of the American Chemical Society*, **61**, 1862, 1939). The C—N linkage in the CONH group has the weakest bond energy and should therefore be the first to break when energy is supplied to the molecule.

All aromatic substances absorb light in the range 2400–3000 Å because of the presence of the benzene ring. Rideal and Mitchell (*Proceedings of the Royal Society of London*, **159** A, 206, 1937) irradiated monolayers of stearic anilide with monochromatic light of wave-length 2537 Å and found that the energy absorbed by the benzene nucleus was used in splitting the CONH linkage:



This observation led to the suggestion that a similar reaction might occur in peptides and proteins containing aromatic residues. However, in peptides and proteins the C—N linkage is more remote from the aromatic nucleus, and the absorbed energy would have to travel through two or more intermediate atoms to reach the site of the reaction.

To test whether the absorbed energy can be transmitted through these distances, Dr. Carpenter first repeated the irradiation of monolayers of stearic anilide, identified the end-products of the photolysis, and confirmed the observations of Rideal and Mitchell. He then irradiated monolayers of benzyl stearyl amine, in which the benzene ring and the CONH group are separated by one CH_2 group, and of β-phenyl ethyl stearyl amine, in which they are separated by two CH_2 groups. He was able to show by identification of the end products that both compounds were split at the CONH linkage (*Journal of the American Chemical Society*, **62**, 289, 1940). The surface potential of the film after irradiation was equal to the surface potential of a monolayer of pure stearic acid. The amines were identified by analysis of the substrates. Aniline gives a red color when diazotized and coupled with β-naphthol; the test is so sensitive that a positive reaction was obtained after only ten minutes' irradiation of a single monolayer of stearic anilide. The benzyl amine and β-phenyl ethyl amine, formed respectively from benzyl stearyl amine and β-phenyl ethyl stearyl amine, were isolated as picrates and identified by mixed melting points with picrates of the pure amines. To obtain sufficient quantities of the latter amines it was necessary to irradiate many successive monolayers, each time removing the stearic acid formed by the photolysis.

Peptides containing aromatic amino acids were investigated next. Glycyl tyrosine and tyrosyl glycine were both broken into glycine and tyrosine by light of wave-length 2537 Å. In the former case the energy travelled through two carbon atoms and one nitrogen atom, and in the latter through three carbon atoms; the amount of energy transmitted was, within 10 per cent., the same by both routes. Alanyl tyrosyl glycine (a tripeptide which had not previously been synthesized) was split at both peptide linkages; all three amino acids could be identified. Tyrosine was analyzed by the usual

colorimetric method. Alanine and glycine were identified by the reaction products with orthophthalic dialdehyde; the former gives a pink compound which remains in the water layer of the reaction mixture, the latter a green compound which may be shaken out with chloroform.

These experiments provide convincing evidence that by irradiation with light of the proper wave-length aromatic amino acids can be liberated from simple compounds in which they are combined through CONH linkages. It seems entirely reasonable, therefore, that by irradiation they should also be liberated from longer chain polypeptides in which they occur. Bergmann has suggested that a protein molecule consists of a single long-chain polypeptide in which the amino acids are arranged in some regular sequence, and that the frequency with which any amino acid recurs in the chain is given by the expression $F = 2^m \cdot 3^n$, in which m and n are positive integers. A protein containing the hypothetical sequence:

ABC T DEFABC T DEFABC T DEF···

in which A, B, C, D, E and F represent aliphatic amino acid residues and T represents the tyrosine residue, should be split by irradiation into the units DEFABC by the removal of the tyrosine. Investigation of these fragments by means of the ultracentrifuge and other techniques might be expected to give considerable insight into the structure of the protein molecule.

Dr. Carpenter has been able to split tyrosine from monolayers of insulin by irradiation with monochromatic light; after twenty minutes' exposure the substrate gives a positive test for tyrosine. If the physiological activity of insulin is a property not of the molecule as a whole but of some specific part of it, the splitting of the molecule into fragments, the subsequent isolation from among these fragments of the physiologically active portion, and the ultimate synthesis of this portion, become problems of the highest importance. It seems quite likely that the liberation of tyrosine is accompanied by fragmentation of the insulin molecule. The photolytic products could probably be separated from the unchanged protein, and perhaps from one another, by electrophoresis in the improved apparatus of Tiselius.

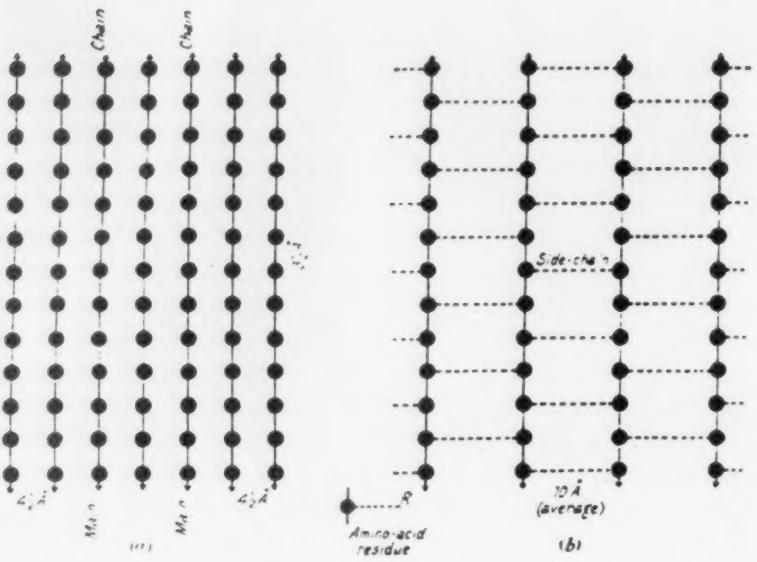
The most serious objection to the use of monolayers for the

study of the photolytic products of proteins is the fact that the protein is denatured during the formation of the monolayer. Even when the protein is irradiated in a solvent in bulk, there is the chance that surface denaturation may occur at the walls of the containing vessel. No technique has yet been evolved which does not introduce the possibility of denaturation of the protein before irradiation can be carried out. Irradiation in a solvent has the advantage over irradiation of monolayers in that larger amounts of split protein are made available for further investigation.

Dr. Carpenter performs all protein irradiations in a refrigerated room to prevent secondary reactions of the protein fragments. He obtains monochromatic light of the required wave-length by means of the light-filtering solutions recommended by Bowen (*Journal of the Chemical Society*, 1935, p. 76), contained in quartz cells. The loss of light intensity is much less than with the large quartz monochromator used by Rideal and Mitchell, and the expense is much lower.

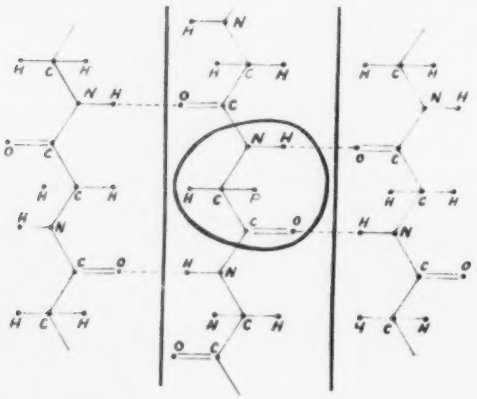
Since the basis for Bergmann's theory of protein structure is in Dr. Carpenter's opinion none too secure, he has examined other theories of protein structure to determine what each would predict concerning the effect of irradiation. Astbury, on the basis of x-ray diffraction studies, largely on stretched fibers of insoluble proteins, has formulated the theory which is represented in Fig. 1. The peptide chains are held in layers by hydrogen bonds or disulfide linkages. The layer levels are held together either by side-chain compounds with the dicarboxylic or diamino acids, or by hydrogen bonds between the layers; either possibility accounts for a distance of 10 Å between the layers. The bond energy of the hydrogen bond is relatively small (less than 8 kcal. per mol in known compounds (Pauling, "Nature of the Chemical Bond," Cornell University Press, 1939, p. 313), compared with 48.6 kcal. per mol for the C—N linkage of the CONH group). The absorbed light energy may therefore be expected to first rupture the hydrogen bonds in the vicinity of the light-absorbing group, and thus separate the layer levels and the parallel chains in each layer; it will then break the CONH linkages on either side of the light-absorbing group (Fig. 2), splitting out the light-absorbing amino acid.

FIG. 1.



The two principal modes of linkage of neighboring protein chains; (*a*) backbone linkage; (*b*) side-chain linkage (according to Astbury).

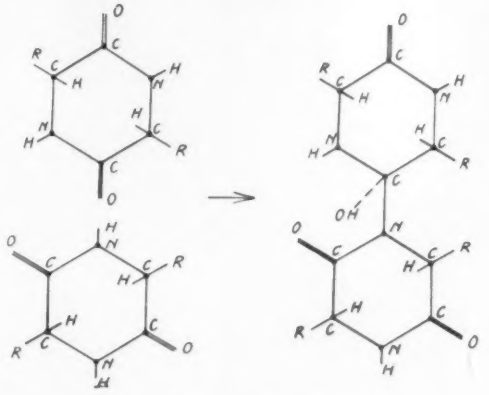
FIG. 2.



Peptide chains held by H-bond linkage after splitting by ultraviolet light.

Wrinch has developed from geometrical considerations a theory to describe the properties of the soluble globular proteins. The assumption is made that the polypeptides do not form an extended chain, but are bent into rings to form a net-like fabric which is held together by means of cyclol bonds, resulting from a type of keto-enol tautomerism, between the NH group of one peptide linkage and the CO group of the one adjacent. Fig. 3 shows the simplest type of bonding to give

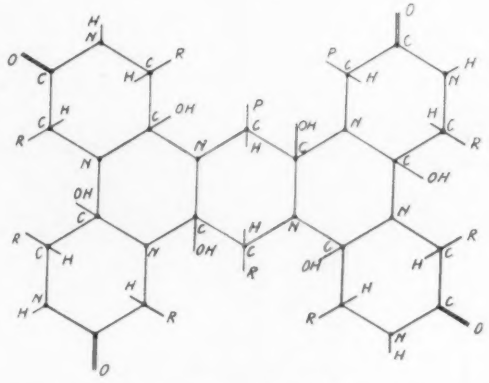
FIG. 3.



Formation of cyclol.

the cyclol type of structure, and the mechanism of formation of the cyclol bond; Fig. 4 shows a section of the fabric. Space-

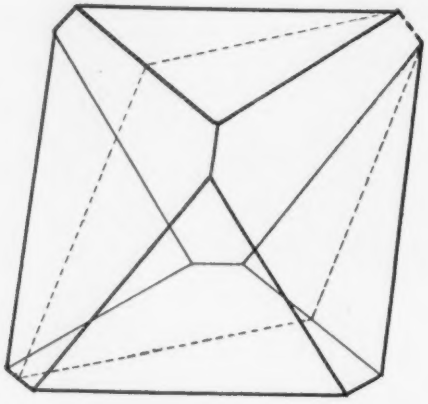
FIG. 4.



Cyclol structure (according to Wrinch).

enclosing, nearly globular molecules may be formed by folding this fabric without deviating from normal valence angles. The structure proposed for the insulin molecule consists of a truncated tetrahedron with four triangular faces and four hexagonal faces (Fig. 5). Fig. 6 shows the fabric formed from one each of these two types of faces, or one-quarter of the total molecule.

FIG. 5.

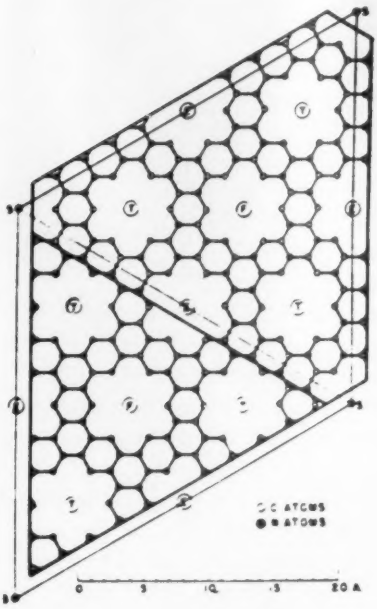


The polyhedral frame of the molecule

The removal of an aromatic amino acid by irradiation involves the rupture of two cyclol bonds in addition to two peptide bonds (Fig. 7). Two aromatic residues situated in adjacent cyclols (Fig. 7) could be liberated from the molecule without great damage to the fabric, but the removal of two situated in the *same* cyclol would cause rupture of the fabric at this point.

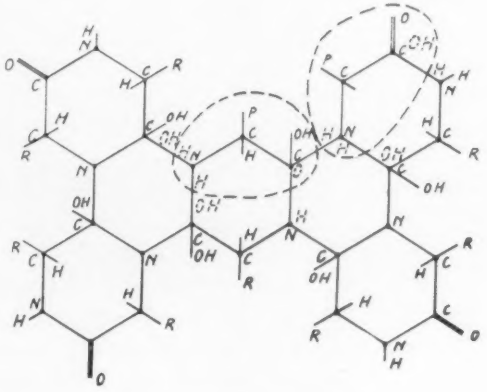
The insulin molecule contains twenty-four tyrosine residues. If these residues were situated two to a cyclol in the six cyclols which form the long diagonal of the piece of fabric shown in Fig. 6, and the six corresponding cyclols of the similar piece forming the back faces of the molecule, irradiation should split the molecule into halves; the dotted line in Fig. 5 marks the line along which fission would occur. Equal pieces would be formed also if the tyrosine residues were situated in pairs

FIG. 6.



A portion of the cyclol fabric representing one hexagonal and one triangular face of the molecule, i.e. one quarter of the portion of fabric making one molecule (according to Wrinch and Langmuir).

FIG. 7.



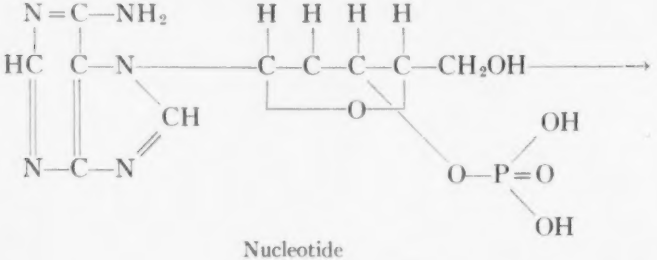
The cyclol structure irradiated.

in any of the groups of three cyclols across the front faces of the molecule, continuing diagonally across the equator of the molecule through the corresponding three cyclols of each of the other three sections of the fabric.

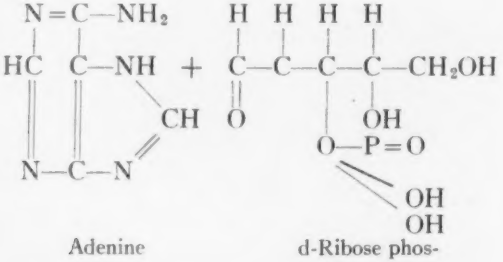
Two small pieces would be split from the molecule, leaving one large fragment, provided the two cyclols near the top corner and the two near the bottom corner of the front faces, and the corresponding four cyclols of the back faces, were composed of aromatic residues; only sixteen of the twenty-four available tyrosine residues would need to be strategically arranged to realize this possibility.

Insulin also contains eight phenyl alanine residues. If these and the eight tyrosine residues not required in the hypothetical structure just described were arranged so as to split out similar small pieces from any two opposite corners of the four which remain, the molecule would be broken into four small fragments and one large one.

Among other classes of substances having high absorption in the ultraviolet and susceptible to cleavage are the nucleic acids. The nucleotide composed of adenine and d-ribose should be split by ultraviolet irradiation into its constituent parts:



Nucleotide



Adenine

d-Ribose phosphoric ester

In this case the adenine residue with its double ring structure and alternate single and double bonds acts as the chromophore group.

Dr. Carpenter's seminar demonstrated the fact that absorbed light energy may travel along a chain and open up the weakest bond linkage in a compound at some distance from the point of absorption of the energy, and that ultraviolet light should be able to open up protein molecules at the weaker bond linkages and enable us to study how proteins are put together.

Studies on Plasma Phosphatase Activity during Embryonic and Tumor Growth.—LEOPOLD WEIL (*The Journal of Biological Chemistry*, **138**, 375, 1941). Previous studies (Weil and Russell, *The Journal of Biological Chemistry*, **136**, 9, 1940) on the plasma phosphatase activity of rats have shown that this enzyme is closely linked with the fat metabolism of the animal. Investigations in this direction have been extended to the study of enzymatic changes occurring during embryonic and tumor growth. It was shown that the plasma phosphatase activity of albino rats remained unchanged from the beginning of pregnancy until about six days before parturition, when a marked drop in the enzyme level was observed. The activity remained low until about four days after parturition, after which a sharp rise was observed, reaching a maximum about three weeks after parturition. The maximum reached was much higher than the original enzyme level. The plasma phosphatase activity then decreased gradually to its original level during transition to the normal state of the rat. The marked increase in the plasma enzyme activity after parturition may be connected with lactation, which involves milk fat production.

The blood plasma of rat embryos and the placenta blood plasma showed a very low phosphatase activity. Young rats belonging to the same litter possessed a low plasma phosphatase activity until they reached the age of about one month, at which time a sharp rise in the plasma enzyme activity was observed. This increase was shown not to be attributable to dietary changes.

Rats with Jensen sarcoma did not show any change in

their plasma phosphatase activity during tumor growth nor did the regression of the sarcoma have any influence on the plasma enzyme activity.

The State of Dispersion of Gelatin in Concentrated Potassium Thiocyanate Solutions.—ELMER O. KRAEMER (*The Journal of Physical Chemistry*, **45**, 660, 1941). The sedimentation constant, diffusion constant, and intrinsic viscosity of Eastman de-ashed gelatin in two-molar potassium thiocyanate were measured at temperatures between 20 and 35° C. in order to determine the effect of the gelation-preventing agent (potassium thiocyanate) upon the molecular characteristics of the gelatin. The molecular weight was calculated to be $1–1.2 \times 10^5$, the frictional ratio was about 3, which is higher than for any protein hitherto studied, the intrinsic viscosity at 25° was 0.72, and the effective axial ratio was about 40. It was concluded that there is no marked difference in the molecular size and shape or degree of hydration for gelatin in aqueous solutions above 35° or in two-molar potassium thiocyanate solutions at room temperatures. The data confirm the idea that the gelatin molecule is tightly folded in solution, resembling the folded molecule of contracted collogen.

BOOK REVIEWS.

LIFE ON OTHER WORLDS, by H. Spencer Jones. 299 pages, plates, illustrations, 14 × 21 cms. New York, The Macmillan Company, 1940. Price $3.00.

The very title of this book arouses curiosity. Whenever man has paused to wonder about the unknown, the possibility of life on other worlds has received its share of attention. The subject has grown from the mere off-hand controversial stage to one where the application of all knowledge has sought the answer. In substance it is still controversial with many arguments and much evidence pro and con, so that when the title of this book comes to hand, there is curiosity as to just what this author thinks about it and what he has to back his conclusions.

Of course any discussion of this subject must be based on our present conception of life and the necessities which are required for its existence. Forms of life other than those with which we are familiar are out of the picture. The book takes this into account and proceeds to first present a picture of the Universe as provided by modern astronomy and a survey of the conditions for the existence of life. In further preparation for a discussion of the subject proper, there is an outline of the methods open to the astronomer for determining the situation on other planets such as the atmosphere and its composition and this with relation to the earth's atmosphere. For the solar system there is shown to be a wide diversity of conditions, with Venus appearing to be a place where life may be on the verge of coming into existence and Mars where life is on the ebb. Various planets are taken up individually, giving results of observations and calculations. Expectancy of direct evidence of animal life on the moon is stated.

Attention is then drawn from the solar system to the possibility of life on some of the planets belonging to one or another of the innumerable stars in ours or another universe. Because of the difficulties resulting from the greater distance of these, resort is made to an examination of the origin of the solar system in hopes that there might be some guidance. This shows that the conditions needed for birth to be given to a planetary system may be so exceptional that amongst the vast number of stars in any one stellar universe we may expect to find only a very limited number that have a family of planets; and amongst these families of planets there cannot be more than a small proportion where the conditions are suitable for life to exist. However, if the proportion of planets on which life can exist is not more than one in a thousand, or even one in a million, the total number of worlds that are suitable for life would yet be considerable, so vast is the scale on which the universe is constructed.

The book gives quite a thorough coverage of the subject without going into too great technical detail. In fact, the layman who desires a many sided examination of the subject will have little difficulty in following it. The author generally has made an exceptional exposition of presenting the astronomical and physical sides in a language understandable by those who have only a passing acquaintance with these subjects. The illustrations help considerably.

R. H. OPPERMANN.

AN INTRODUCTION TO THE KINETIC THEORY OF GASES, by Sir James Jeans. 311 pages, illustrations, 15 × 23 cms. New York, The Macmillan Company. Price $3.50.

The author states in the Preface of this book that it is intended to provide such knowledge as is required by the average serious student of physics and chemistry. Further, it is hoped it will also give the mathematical student the equipment he should have before undertaking the study of specialist monographs. The book presents a development of the kinetic theory as far as it can be developed without departing from the Newtonian laws. The inadequacy of these laws is pointed out in certain problems.

The treatment starts with a preliminary discussion of some of the principal problems of the kinetic theory, of sufficient extent as to orient the student with the main concepts of the theory. Then a more detailed study of various special problems is made, the first of which is concerned with the calculation of the pressure in a gas. Under the heading of Collisions and Maxwell's Law there is taken up the law of distribution of velocities leading up to the state of a gas which is not altered by collisions—when the density and law of distribution of velocities remain statistically the same at every point of the gas throughout all time. This is specified as Maxwell's law. Building further upon the foundation now laid, there is discussed the various problems associated with the free path which molecules describe between collisions, the transport of momentum or viscosity, the conduction of head and diffusion.

Up to this point molecules were treated either as elastic spheres, exerting no forces on one another except when in actual collision, or else as point centers of force, attracting or repelling according to comparatively simple laws. There now follows under "General Statistical Mechanics and Thermodynamics" a discarding of such restrictions, and the question regarding the molecules as general mechanical structures is taken up. Any complexity of construction is allowed with any number of parts capable of any kind of internal motion and exerting upon one another forces of any type. The subject of calorimetry and molecular structure is studied in detail in the final chapter of the book.

The treatment adequately meets the purpose for which it was intended. The newer system of laws constituting the modern theory of quantum mechanics, being beyond the scope of the book, is not covered. Clarity in presentation is a feature. A contributing factor to this is the reference throughout the text to commonplace conditions analogous to the particular topic discussed. Those who are qualified to study the subject will find in this book a treatment readily understandable.

R. H. OPPERMANN.

STORAGE BATTERIES, A GENERAL TREATISE ON THE PHYSICS AND CHEMISTRY OF SECONDARY BATTERIES AND THEIR ENGINEERING APPLICATIONS, by George Wood Vinal. Third Edition, 464 pages, illustrations, 16 × 24 cms. New York, John Wiley & Sons, Inc., 1940. Price $5.00.

This is the third edition of a well known text. The editions of 1924 and 1930 have been a standard work for study and reference. Since 1930 there has been considerable advance in the industry in theory, manufacture and use and

the present edition is intended to recount these advances so as to present the subject in a present-day light.

The pattern of presentation is based on the assumption that the storage battery is an electrochemical apparatus. As such it is treated first from the standpoint of the chemical, involving the nature and properties of the materials and the reactions which occur during charging and discharging; second, the physical which includes a study of the electrical input and output, the factors which affect the capacity, and the theory of the transformation of chemical energy into electrical energy and vice-versa; third, the engineering applications, including all that is necessary to an adequate understanding of the nature and performance of storage batteries.

The sequence of presentation is a logical one for the purpose of covering the subject in its entirety, yet portions of the book may be segregated to suit specific interests. After a brief introduction, there is taken up in order the materials and methods of manufacture of the different types of cells; the electrolyte including its production, properties, preparation and shipment; theory of reactions, energy transformation and voltage; methods of capcity rating and factors determining capacity; operation which covers charging, discharging, regulation, and sources of trouble; resistance and efficiency; testing for various purposes; present day uses. With regard to uses reference is made to many different applications. They include telephone work, railway service, marine applications, emergency lighting, automotive starting, and aircraft uses.

There is much helpful information in the way of tables, and curves, and formula. In the more technical phases of the subject at appropriate places there are worked out examples. The illustrations also assist greatly to understanding. At the end of the book there is a comprehensive subject index facilitating its use for reference.

The book itself has a flexibility of application. It may be used to advantage by the student of the subject as a whole, by the electro-chemist, by the engineer, by the industrialist, by the electrician, by the service man and others. In fact anyone who uses or has to do with storage batteries may locate in this book something of interest and value.

R. H. OPPERMANN.

PHYSICAL CHEMISTRY, A BRIEF COURSE WITH LABORATORY EXPERIMENTS, by Louis J. Bircher. 429 pages, illustrations, 16 × 24 cms. New York, Prentice-Hall, Inc., 1940. Price $3.00.

A survey of the subject matter of physical chemistry shows that this field of knowledge covers a wide variety of topics and is vast in content.

This textbook is divided into four parts, each part stressing a phase of the problems of solubility and reactivity: Part 1—structure of matter; Part 2—transitions from state to state; Part 3—physico-chemical change; and Part 4—physical chemistry experiments.

A wide range of subject matter is included. For example, it is unusual to meet such terms as "fugacity" in a text of this sort. The book is well printed and each chapter is terminated with a series of questions which will help the first year student in a material degree to comprehend chemical theory and acquire proper conception of the intimate relation between chemistry and physics.

G. S. GARDNER.

FUNDAMENTALS OF PHYSICAL CHEMISTRY, by Earl C. H. Davies. Second Edition, 447 pages, illustrations, 15 × 22 cms. Philadelphia, The Blakiston Company. Price $3.50.

Physical Chemistry, by Davies, might be considered an elementary textbook on physical chemistry. However, there is little resemblance to the average physical chemistry text. The viewpoint is modern and emphasis is placed on phases of the subject which are of interest in modern life.

This second edition is more extensive than the preceding edition. The number of chapters is the same but they have been rewritten and enlarged. The work is written in a clear style, well illustrated and each chapter is terminated with exercises.

The book is apparently intended for first year college students, since all difficult mathematics is avoided. It can be recommended for general reading.

G. S. GARDNER.

WHAT ARE THE VITAMINS, by Walter H. Eddy. 247 pages, illustrations, 16 × 24 cms. New York, Reinhold Publishing Corporation, 1941. Price $2.50.

The study of vitamins has become very extensive and many books and papers have been written on the subject. The story of vitamins although not a very old one has been talked about so frequently in the last few years that we wonder how we existed before they were brought to our attention.

The present volume contains much material that has been gathered through research and the work of the author. It is a survey of each of the known vitamins and written in a more technical form than some of its predecessors.

The work is illustrated and contains extensive bibliographies, a table of vitamin values and a well arranged author and subject index.

P.

CHEMICAL ANALYSIS OF ALUMINUM, compiled by the Aluminum Company of America. 120 pages, illustrations, 14 × 21 cms. New Kensington, Aluminum Company of America, 1941. Price fifty cents.

This work, now in its second edition, includes both revisions of the first edition and new material. It contains methods standardized and developed by the chemists of the Aluminum Company of America under the direction of H. V. Churchill and R. W. Bridges.

The book gives some rapid methods for the analysis of aluminum and discusses impurities and commonly used alloys. The final chapter deals with evaluation of Albron powder and paste.

Copies may be obtained from the Aluminum Research Laboratories, New Kensington, Pennsylvania, by enclosing fifty cents for each copy desired.

P.

RADIOACTIVITÉ ET TRANSMUTATION DES ATOMES, PAR THEODORE KAHAN. 224 pages, illustrations, 11 × 17 cms. Paris, Armand Colin, 1940. Price 15 francs.

M. Théodore Kahan, whose competence for the task has been shown in numerous scientific works, here gives us a general view of our present knowledge of radioactivity and the transmutation of the elements. With clarity and with no

sacrifice of precision, he has traced the development of nuclear physics from the earliest experiments to those contemporary investigations which have made possible the realization of one of the oldest dreams of humanity—the artificial transmutation of matter. Though the book is small enough to be slipped into one's pocket, it gives a detailed account of the latest discoveries and their theoretic interpretations, to which the author has himself made valuable contributions. In our age, when research into every source of power has become of the utmost importance, great interest is attached to the problem of the disintegration of matter, largely because of the prodigious quantities of energy which may—perhaps—be obtained and utilized. Both this point and that of the medical uses of spontaneous and artificial radioactivity are clearly brought out and M. Louis de Broglie—himself, of course, preeminent in the field—has contributed an illuminating preface.

E. E.

PRACTICAL SOLUTION OF TORSIONAL VIBRATION PROBLEMS, by W. Ker Wilson. Vol. 1, Second Edition, 731, illustrations, 14 × 22 cms. New York, John Wiley & Sons, Inc., 1940.

The importance of this subject has and is growing at a very fast rate. The application of the internal combustion engine, driving shafts, transmitting pulsating torques and creating vibrating problems has contributed to this to no little extent. Much interest has been shown in the study of vibrating in general and many satisfactory results have been obtained both in theory and in practice. Torsional vibration presents a somewhat different problem. Its particularly insidious nature is due to a capacity for destructive action without displaying the external symptoms which are usually very noticeable with other forms of vibration.

This book attempts to give the principles and computation details of torsional vibration in a manner suitable for everyday use. It is Volume 1 of a two volume set and is in its second edition, the first edition having been published in 1935. The treatment is in logical progression from the simple to the more complex. It starts with an introduction describing stress, strain, elasticity, etc., showing that a shaft carrying a series of masses may have several modes of free vibration distinguishable by degree numbers. This leads into a discussion of natural frequency calculations first using ideal systems, then oscillating systems actual installations. Flexible couplings is a subject containing much of interest in explanatory matter as to different kind of couplings, and materials and their properties effecting solution of torsional vibration problems. The next topic is the determination of torsional vibration characteristics of geared systems, which is followed by the last and most extensive treatment, that on the determination of stresses due to torsional vibration at non-present speeds. Amongst the data and calculations given here are typical values of harmonic components of tangential effort of 2 stroke and 4 stroke cycle oil and petrol engines and of steam engines, harmonic torque energy in multi-cylinder engines, air screw engines, vee engines, etc. An appendix is devoted to the effective inertia method of torsional vibration analysis with special reference to aero-engine-air screw systems. It is shown that any system capable of executing torsional oscillation can be regarded as composed of two portions, one of which is regarded as an elastically connected portion which can be replaced by a single equivalent mass rigidly connected to

the other portion at the point of division. This device is useful in the case of complex systems. The method leads to a comparatively simple experimental means for determining the natural frequencies and other torsional vibration characteristics of systems containing members which have complex or mathematically indeterminate mass—elastic characteristics.

The author has taken considerable pains to make his presentation in a simple manner. Discussion proceeds to a point where worked out examples promote clarity. The numerous diagrams, tables and illustrations also help to facilitate understanding. No hesitation whatever is made in giving workable data and information from actual installations in the various fields noted in the subtitle of the book. Aside from the table of contents there is given a list of worked examples. This together with a bibliography, name and subject index enhances the book's value as a reference. Designers will find here a practiced text which will be of continuous use.

R. H. OPPERMANN.

THE SOCIAL RELATIONS OF SCIENCE, by J. G. Crowther. 665 pages, 15 × 22 cms. The Macmillan Company, 1941. Price $3.50.

The title of this book has the ability to convey different impressions to different people. To some it may suggest a "crack-brained" theory similar to what the world has witnessed in various forms in the recent past. To others it may suggest a study of something new to be devoured entirely or in part with the result of a cure-all for the world's ills. And still others may view it as a subject to be avoided on the grounds that it holds no promise. The fact of the matter is, the book contains all of these and more. It is a broad coverage of a subject which the author has succeeded in definitely designating as well as setting definite borders.

One of the primary factors which come to mind in evaluating a book such as this is the qualifications of the author. J. G. Crowther is the Scientific Correspondent of the Manchester Guardian (England). In the past eleven years he has written fourteen books, all of which emphasize the growth of science in relation to social development. He was invited in 1937 by President Canant of Harvard University to deliver a course of lectures and in 1938 he toured the United States speaking on the social relations of science and the interpretation of social events in terms of the development of science.

This book is an expansion of these themes. The development of subject is through a history of science in the light of social conditions as they existed and from this there is drawn the motives and results of discoveries and scientific progress. The influence of society is kept in the forefront. The nature of science is demonstrated as a social product by elucidating the roles of freedom, class interest, national ambition and the repute of manual labor. Much of this the well read person already knows. But the author has rounded his subject to such an extent that there is much more that cannot readily be recalled by the average reader. In this respect the book is instructive, especially so since most of the divisions give references from which the material is taken. Social and economic conditions may be placed in this class.

The implications drawn are of course those of the author. Here is where confusion and differences of opinion will exist and here is where interest is

sharpened. Given the case through facts, it is safe to say not many, if any, readers will be in complete agreement. It becomes a matter of weighing the facts and placing them in their proper order to reach the result of the social relations of science. And even when this is done (the author has tried to do it according to his ideas), there still remains much doubt whether all essentials are considered. The story is not all convincing. Nevertheless it must be recognized that the author has made a contribution toward encouraging thought that may have promise. The book is well written, easy to read, and informative. It must not be believed that the treatment is conclusive, for were it taken in this manner and tried accordingly in a practical way, the results would be dangerous. The book is an honest effort at making a stepping-stone to better living and if taken this way it can be recommended.

R. H. OPPERMANN.

PHYSICAL CHEMISTRY, by E. A. Moelwyn-Hughes. 660 pages, illustrations, 18 × 28 cms. Cambridge University Press, 1940. Price $9.50.

The purpose of this book, according to the author, is to present the fundamental principles of the new physical chemistry and the application of them to a number of simple problems so arranged as to form a logical introduction to the specific treatment of the most relevant of current physio-chemical themes. While "an introduction" is the subtitle of the book, the greatest stress is laid on it and the book's value lies here rather than broad coverage over the vast and important fields of physical chemistry.

The book is divided into two parts. The first is devoted to general principles. Experimental and theoretical paths are followed in order. Attention is given the experimental foundations and the mathematical formulation of the kinetic-molecular theory. The quantum theory is introduced harmoniously with its classical predecessor and there is shown quite clearly the relation of both theories to the facts. Part one is concluded with a discussion of the elementary forms of matter, and the description and the application of the laws of thermodynamics to problems of chemical interest.

Part two of the book is devoted to the application of the principles of modern physical chemistry to specific systems, namely monatomic, diatomic and triatomic molecules. Stable chemical equilibria is discussed of gaseous systems at dilutions sufficiently great to justify the use of the ideal gas laws. There logically follows a treatment on chemical kinetics in the homogenious gas phase. The last chapter of the book deals with the branch of crystal chemistry concerning the determination of the structure and interconstituent dimensions of certain simple crystals and the nature of the energy which is responsible for their stability.

The treatment, as far as it goes certainly is complete in itself. All Theorems are derived. The assumption is made that no greater knowledge of mathematics is possessed by the reader than the student of mathematics has of chemistry. There is an adequate author and subject index in the back which enhances the value of the book as a reference work. Those qualified for the study of this subject should find here a very helpful text.

R. H. OPPERMANN.

RADIOLOGIC PHYSICS, by Charles Weyl, S. Reid Warren, Jr. and Dallett B. O'Neill. 459 pages, 15 × 23 cms. Charles C. Thomas, Springfield, Illinois, and Baltimore, Md., 1941.

With the ever increasing physical knowledge obtained from researches and development of apparatus there has grown a definite need by workers in many fields to not only have a basic training but to keep abreast of the significance of current discoveries in the branches of physics which have a bearing on their primary interests. Nowhere is a better illustration of this than in radiology. Dr. Eugene P. Pendergrass, Director of the Department of Radiology in the Hospital of the University of Pennsylvania, states in the foreword of this book, "In order that a physician shall develop and be worth his salt in the modern department of radiology, it is necessary for him to master at least the fundamentals of modern physics and according to our ideas, it forms a most important part in his instruction."

The book is an outgrowth of several years of teaching by the authors in the Graduate School of Medicine in the University. The authors state that it has been their aim to develop a reasonably complete introductory text and to give adequate preparation for the study of the more advanced and specialized papers and treatises on the physics of radiations and the design, construction and operation of x-ray and cognate apparatus. The book is divided in two parts. The first part starts with a discussion of scientific methods of analysis, what it is, why, and what can be expected from it. Then the elements of electrical engineering are explained in so far as they are necessary to an understanding of radiological apparatus. Subjects such as electromagnetism, the electric current and its analysis, electrical measuring instruments, transformers and power apparatus, electronics, and apparatus for electrotherapy, diathermy, high-frequency surgery and radiation are explained. This covers some 200 pages.

The second part of the book is devoted to radiant energy and its interactions with matter. This opens with a historical summary of the study of radiation and it shows how the theory of radiation has evolved as new experimental data were obtained. Progression then follows in order through x-rays, radio-activity and nuclear physics, measurement and control of x-rays and gamma rays, physical aspects of the use of x-rays and gamma-rays for therapy, fluoroscopic and roentgenographic techniques.

One of the unusual features of construction of the book is that the appendix contains the elements of trigonometry and calculus which are necessary as a prerequisite to follow the text. Another feature in this category is the originality and simpleness of method of presentation. Liberties are taken, perhaps more than is usually found in a text of this nature, in reaching out beyond strict limitations of the subject in the interest of clarity. Considering the fact that the subject in a sense straddles portions of two distinct fields, and the situation of the student for whom the book is intended, these features are by no means a drawback. Indeed they enhance the value of the book. The aims of the authors of the book have certainly been accurate. Prospective students of the subject would do well to examine it from the standpoint of providing a necessary fundamental knowledge. There is also a degree of value which is not mentioned. In addition to being directed toward the medical profession, electrical engineers whose interests lie in this field would profit by using part two of the book especially.

R. H. OPPERMANN.

ELECTRIC AND MAGNETIC FIELDS, by Stephen S. Attwood. 430 pages, illustrations, 14 × 23 cms. Second Edition. New York, John Wiley and Sons, Inc. 1941. Price $4.50.

This book covers considerations in the field of electrical design, which, until recently, have perhaps not received entirely complete attention in electrical engineering courses.

Man's first knowledge of electricity and magnetism began with observations having to do with electric and magnetic fields, but as the art developed useful applications directed attention to circuits and considerations of electric current flow. With the exception of special problems, the careful study of electric fields has been given but small attention and the analysis of magnetic fields in general have been treated only in an approximate manner.

The growing importance of electronics has materially changed the concepts of an electrical engineering education. Again electric fields became paramount in this most important and promising development. This book therefore, is very pertinent indeed, in its careful treatment of the subject.

Eight chapters are devoted to consideration of electric fields from both a theoretical and practical aspect. The section includes the solutions of problems arising in the design of insulators, electric shielding, condensers and a geometry of electronic tube elements.

There are four chapters devoted to the consideration of magnetic fields, including methods for calculating such fields associated with coils, single and multiple straight wires and the influences of moving conductors carrying current.

Three chapters are given to considerations of fields in ferrule magnetic materials including fundamental concepts of core losses, incremental permeability and procedures for mapping the magnetic fields for various types of mixed paths.

Combined electric and magnetic fields are assigned a section for the consideration of wave propogation and electro magnetic radiation.

The book closes with two appendices containing useful statistical data and a very excellent historical outline covering the general development of our present concepts of electricity and magnetism.

The book includes sixteen tables of statistical data of continued usefulness for the designer and researcher, constituting a valuable feature in bringing this material conveniently into one volume.

While the book has been prepared as a text book, the subject matter and its treatment is of such active interest in present-day work that it might well be termed a handbook for those active in this field.

W. G. E.

PUBLICATIONS RECEIVED.

Organic Chemistry, An Introduction to the Carbon Compounds, by Nicholas D. Cheronis. 728 pages, 15 × 24 cms. New York, Thomas Y. Crowell Company, 1941. Price $4.00.

Amos Eaton, Scientist and Educator, 1776–1842, by Ethel M. McAllister. 587 pages, 16 × 24 cms. Philadelphia, University of Pennsylvania Press; London: Humphrey Milford: Oxford University Press, 1941. Price $5.00.

The Manuscript, A guide for its Preparation, by John Wiley & Sons. 75 pages, illustrations, 15 × 23 cms. John Wiley & Sons, Inc., N. Y. London: Chapman and Hall, Limited. 1941. Price $1.00.

An Introduction to the Theory of Newtonian Attraction, by A. S. Ramsay. 184 pages, 14 × 22 cms. Cambridge University Press, 1940. Price $2.50.

The Theory and Applications of Harmonic Integrals, by W. V. D. Hodge. 281 pages, 14 × 22 cms. Cambridge University Press, 1941. Price $4.50.

Between Physics and Philosophy, by Philipp Frank. 238 pages, 14 × 22 cms. Cambridge University Press, 1941. Price $2.75.

Partial Differential Equations, by Frederic H. Miller. 259 pages, 16 × 25 cms. Illustrations. John Wiley & Sons, Inc., New York. 1941. Price, $3.00.

College Physics, by Henry A. Perkins, Sc.D. 591 pages, 16 × 24 cms. Illustrations. New York: 1941, Prentice-Hall, Inc. Price $3.50.

CURRENT TOPICS.

Gold Production.—With total gold production valued at approximately $25,375,000 during the past year, Alaska hit an all-time record which surpassed even the great gold rush days, W. C. MENDENHALL, Director of the Geological Survey said in making a preliminary report of the Territory's total 1940 mineral production. This amount is nearly $2,100,000 more than the value of gold output in 1939 and brings the total value of gold production in Alaska, from the beginning of recorded mining in 1880, which was 13 years after the Territory was purchased from Russia for $7,200,000 to the present, to about $561,311,000. Production in 1940 of other minerals besides gold, including platinum metals, tin, antimony, quicksilver, and coal increased in quantity and value. The entire production of all minerals for the year was valued at approximately $27,658,000—nine and one-fourth per cent. more than in 1939. The 1940 production brings the total value of all minerals produced in Alaska since 1880 to more than $730,000,000 Director Mendenhall stated.

R. H. O.

American Standard Association Proposed Method For Determining Speed of Film.—M. E. RUSSELL of the Eastman Kodak Company describes the proposed standard method for determining the photographic speed of roll film, film packs and miniature camera films as being built about the concept that photographic speed is to be considered as inversely proportional to the minimum camera exposure which a negative material must receive in order that an excellent print may be made therefrom. The method consists of plotting a characteristic curve (that is, density *vs.* log exposure) of the material being tested for a particular set of exposing and developing conditions and then determining certain constants from the characteristic curve. In the making of a characteristic curve the photographic material is given a series of exposures on an instrument known as a sensitometer. In this instrument the spectral quality of the radiation and the time of exposure are made to match the average conditions in photographic practice as closely as possible. The exact shape of the curve is influenced by the type of exposure and development used, making it imperative these conditions be exactly those for which the characteristic curve is intended

to apply. Usually the finished sensitometric strip looks like a series of gray areas. After the sensitometric strip has been exposed and processed the blackness or density of each of the exposed areas is measured by a densitometer. This method of determining speed has been substantiated not only by the statistical fact that sensiometric results agree excellently with those found by actual picture-taking practice but by theoretical considerations as well. Since the quality of a photographic print depends upon the manner in which brightness differences have been recorded by the negative and the print materials, it is clear that any method for properly evaluating speed must be based upon the ability of the material to record brightness and differences. The new method in laying emphasis on the gradient characteristics of a material, is distinctly superior to the previously used methods for determining speed.

R. H. O.

1941 Meeting of Midwest Power Conference.—The 1941 meeting of the Midwest Power Conference will be held April 9–10, at Chicago. This conference is sponsored annually by Illinois Institute of Technology (formerly Armour Institute of Technology) with the cooperation of seven other midwestern universities and colleges and the local sections of the Founder and other engineering societies. The conference is entering its fourth year under the present sponsorship. "The purpose of the Midwest Power Conference," according to Professor Stanton E. Winston, Conference Director and Associate Professor of Mechanical Engineering at Illinois Institute of Technology, "has been established as that of offering an opportunity for all persons interested in power production, transmission, or consumption to meet together annually for the study of mutual problems, free from restrictions of required memberships in technical or social organizations. It is felt that academic sponsorship of a conference permits the freest possible discussion ranging from the technical through the economic and into the social aspects of the subject." The tentative program of the 1941 meeting, as outlined by the directorate of the Conference, includes sessions on Central Station Practice, Stationary Prime Movers and Plant Auxiliaries, Hydro Power, Electric Power Transmission and Distribution, Feedwater Treatment, and Industrial Power Plants. The nation's power problems are of vital importance in this day of industrial mobilization and national emergency. The sponsors of the conference extend to all who are interested in such problems a cordial invitation.

R. H. O.

Industrial Health Defense.—Development of industrial ventilation standards well deserves the increased attention being given it, particularly as our preparations for national defense mean the introduction of new hazards to employee health and efficiency, and because existing hazards become more dangerous under the stress of increased output. While data of a fundamental nature on industrial ventilation must come from laboratory studies, it is a mistake to assume that what is needed can be 100 per cent. provided by researchers. Industrial plant engineers must determine much of the required data by means of field studies. How to make such plant or field studies is the subject of the discussion in *Heating, Piping and Air Conditioning*, Vol. 13, No. 1, by W. C. L. HEMEON, Engineer with Massachusetts Division of Occupational Hygiene. In some cases, the educated senses of sight and smell are excellent methods of determining the adequacy of a ventilating system. Usually, however, instruments and devices of one kind or another are required. Among them are chemical smoke producers for use when the exact source of contamination is known to be limited to a definite area and no visible fume or smoke is generated by the industrial process. The use of such a device permits one to observe the air currents induced by the exhaust and thus to determine to what extent the positively induced air currents cover the zone of contamination. Of the devices available for this purpose, the smoke tube designed by the U. S. Bureau of Mines is most convenient for industrial purposes. Other more homey instruments also have their uses in the plant. The U-tube manometer for estimating the flow rate of air into an exhaust opening by measuring suction in the pipe right after the inlet, is an example. Likewise, there is the pitot tube which has wide application in laboratory studies but is rarely used in the field for measurements of factory exhaust systems for many reasons. By the use of simple accessory equipment, the pitot tube becomes a very useful instrument for the accurate determination of air velocities in industrial exhaust systems.

R. H. O.

Science in Democracy.—" What I have suggested means a closer fusion of science with liberalism," said DR. CHARLES E. KELLOGG of the U. S. Department of Agriculture, summarizing his address before the American Association for the Advancement of Science. "Democracy is the institutional expression of liberalism. The main outlines of our democracy were developed prior to the modern age of science. Gradually and unevenly was science accepted in modern society. We need now a more homogenous amalgam of the two concepts—liberalism and science. Liberalism without science be-

comes a sloppy sentimentalism. It expresses itself in whimpering or shouting where clear thought and objectivity might be successful. Science without liberalism leads to efficiency conceived in materialistic terms—but a philosophy of efficiency coldly silent about human values and ultimate goals, for either the individual or society. Given these two concepts of democracy and science, dominant together, our people can find strength and happiness. Scientists have a large responsibility to help bring together the principles of science and those of democracy in a dynamic pattern of social organization within which all may find opportunity and justice. Up to now they have scarcely taken the trouble. A great deal depends upon whether they do so in the future, while there is time."

R. H. O.

Soybean Oil Makes Traffic Paint.—Durability and quick drying are the two main essentials of traffic paints, used on pavement to mark out traffic lanes and parking spaces and to paint signs on the road surface. A good traffic paint should also retain its color for as long as it will last in use. Soybean oil treated by a new process just developed at the U. S. Regional Soybean Laboratory in Illinois, promises to meet the needs for traffic paint and to compete in this respect with imported tung oil if Asiatic conditions interfere with imports. Soybean oil has made an excellent record for durability in ordinary paints and varnishes, but it dries too slowly to serve as a base for traffic paint. But recent research at the laboratory, according to DR. R. T. MILNER, director, shows that heating the oil with an organic chemical that acts as an "accelerator," speeds up thickening of the oil, wh ch leads to a fast drying varnish. Addition of a resin or gum and pigment, and of a thinner, forms a satisfactory traffic paint, the experimenters think on the basis of early tests. A large scale test under service conditions on highways is starting soon. Traffic paints have called for importation of thousands of gallons of tung oil. If the new paint proves satisfactory it will be an outlet for thousands of gallons of soybean oil, and doubly welcome because the soybean crop has been increasing rapidly in recent years. The Bureau of Agricultural Chemistry and Engineering points to this research work as a typical example of the kind of investigation that is now getting under way at the four regional laboratories devoted to discovering new industrial uses for farm products.

R. H. O.